A FORTRAN COMPILER FOR THE PDP-8 COMPUTER

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THESIS

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ABSTRACT

The design and implementation of the FORTRAN/8 compiler for the PDP-8 computer is described. This compiler was written using the XPL Compiler Generator System and runs on an IBM System 360. FORTRAN/8 accepts FORTRAN as the source language and generates code acceptable for execution on a PDP-8 computer.

TABLE OF CONTENTS

LIST OF DRAWINGS

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I. INTRODUCTION

FORTRAN/8 is a FORTRAN compiler which generates code acceptable for execution on a PDP-8 computer.[1] The compiler was written using the XPL Compiler Generator System [Ref. 1], and was implemented on an IBM System 360.

A. STATEMENT OF THE PROBLEM

A PDP-8 system consisting of a PDP-8/S computer, teletype, and PI-1250-1 data handling system has been assigned to the Oceanographic Department at the Naval Postgraduate School. This system is portable and frequently removed from this facility for use on oceanographic assignments. Consequently, users are denied the possibility of continual testing of FORTRAN programs.

The FORTRAN/8 compiler was designed to provide users with the possibility of testing FORTRAN programs when the PDP-8 system was not available.

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[1]The PDP-8 series is referred to as PROGRAMMED DATA PROCESSORS and are manufactured by DIGITAL EQUIPMENT CORPORATION, Maynard, Massachusetts.

B. TERMINOLOGY

Throughout the discussion which follows, a general familiarity with basic computer terminology is assumed. The following notions are essential for comprehension of the remainder of the paper.

1. Compiler

A compiler is a computer program which translates source programs written in some higher-level language (e.g., FORTRAN, or ALGOL) into machine language. The generated machine language is referred to as the object module.

2. Backus-Naur Form

Backus-Naur Form (BNF)[2] is a method of formally specifying a context-free phrase-structure grammar. It is presented in detail in the "Revised Report on the Algorithmic Language ALGOL 60," [Ref. 2].

In BNF, the brackets " < " and " > " enclose defined terms, but are omitted for basic elements of the language being described. Symbols ": : =" and " | ," which mean "is defined as" and "or," are used in the definitions of terms.

As an example, the definition

<identifier> ::= <letter> | <letter> <digit>

states that an <identifier> is defined as a <letter> or a <letter> followed by a <digit> . Thus, if <letter> and <digit> are further

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[2] The Backus-Naur Form is also known as Backus-Normal Form.

defined as

<letter> ::= A | B ....Y | Z and

<digit> ::= 0 | 1 ....8 | 9

then an <identifier> can consist of a sequence of letters and digits, as long as the first character is a letter.

BNF is used in the formal definition of the syntax of FORTRAN/8 (see Appendix A).

3. Hash Coding

Hash coding [Ref. 3], also known as scatter storage, is a term used to describe a technique for the storage and retrieval of data within a table. This method uses some feature of the data to be stored in order to calculate a table entry address. If a succeeding calculation selects a cell which is already in use, then a collision is said to exist.

When a collision occurs, one of several methods can be used to store the latest data. One of these methods is to search the table for the next vacant table element. The data is entered into the vacant cell and a pointer is set so that the data can be accessed at some future point.

Hash coding techniques normally decrease the access times for retrieval of data considerably when the data is accessed by content.

4. XPL Compiler Generator System

The FORTRAN/8 compiler was constructed using the XPL Compiler Generator System (CGS) [Ref. 1]. This system is fundamentally composed of two programs: ANALYZER and SKELETON.

XPL, a block-structured language used by the XPL CGS, is a dialect of PL/I. Designed specifically for compiler writing, XPL is easy to learn and contains the necessary constructs for table manipulation required by compilers.

ANALYZER is a program which accepts the BNF specification of a grammar, determines the acceptability of that grammar, and produces a set of parsing decision tables. The acceptability is based on the Mixed-Strategy Precedence (MSP) parsing algorithm used by SKELETON.

The MSP parser is based on simple precedence analysis [Ref. 9], with additional tables to make parsing decisions when more context is required.

SKELETON is a program which, with the addition of the ANALYZER produced tables, will act as a syntax checker and a basis for constructing a compiler. The essential procedures of SKELETON are shown in Figure 1. The complete program is listed in [Ref. 1].

The main body of SKELETON consists of a call to MAIN_PROCEDURE. This call starts the compilation process by calling INITIALIZE to set the global constants. Control of the parsing process is then passed to COMPILATION_LOOP.

Each call from COMPILATION_LOOP to SYNTHESIZE corresponds to an application of a BNF production in the source language. The particular elements for a production are located by SCAN and passed to STACKING. STACKING, a parsing decision function, places the elements in a stack until sufficient elements are available

to cause a stack reduction. If sufficient elements are available for a reduction then REDUCE will search the list of BNF productions seeking a match. PR_OK will be invoked to verify the selected production.

SYNTHESIZE is responsible for associating meaning with the productions of the BNF grammar. It has one parameter which corresponds to the BNF production number. This argument will be applied in the pending reduction.

In SKELETON, SYNTHESIZE consists of a case statement on the production number. The completed SYNTHESIZE in FORTRAN/8 will consist of a giant case statement where each case will correspond to a rule in the grammar. It is within this procedure that the majority of the object code will be emitted.

RELATIONS AMONG PROCEDURES IN SKELETON

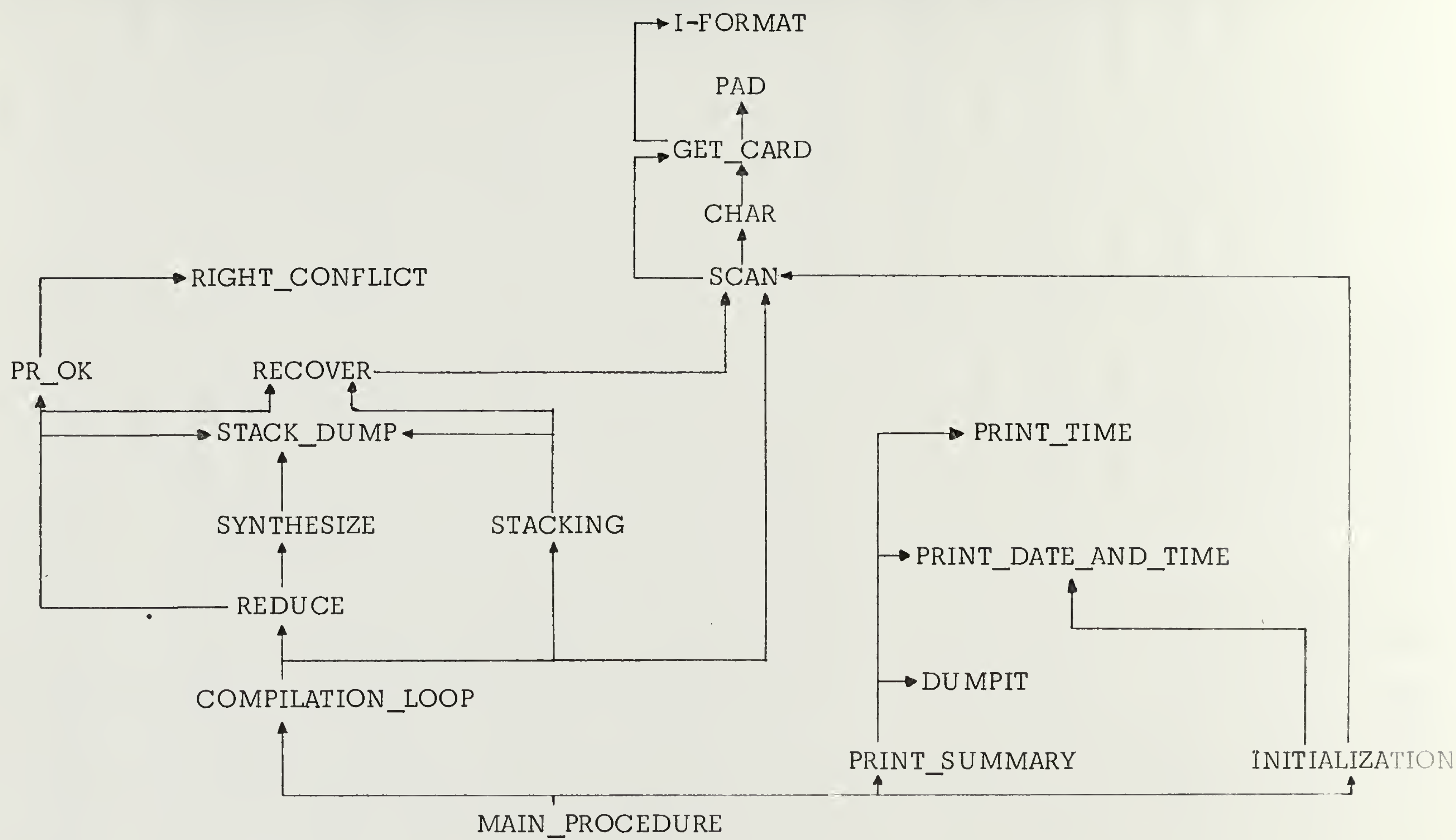

FIGURE 1

II. PDP-8 HARDWARE

The PDP-8 was designed for use as a small-scale general purpose computer using twelve bit binary words and two's complement arithmetic. Each of the four basic components of this computer will be discussed in this section. These components are: (1) arithmetic unit; (2) control unit; (3) memory unit; and (4) input/output units. A complete description of the PDP-8 computer is available from Digital Equipment Corporation [Refs. 7 and 8].

A. ARITHMETIC UNIT

The arithmetic unit accepts data from input devices and transmits processed data to output devices. This unit functions under the direction of the control unit and consists of an accumulator (AC) and a link. The accumulator is twelve bits in length and corresponds to the PDP-8 word size. Bits within the accumulator are numbered 0-11 starting at the left. The link bit, logically a part of the accumulator, is complemented whenever binary operations cause a carry from the accumulator.

Octal numbers within the range -3777_8 to 3777_8 (or -2047_{10} to 2047_{10}) can be represented in the accumulator. The zeroth bit (leftmost) is reserved for the sign bit and the presence of a "1" in this position indicates a negative number.

Inclusion of the Floating Point Package [Ref. 4] allows interpretation, execution, and input/output of numbers ranging from $-10^{\pm 63}$

to $10^{\pm 63}$. This package requires the use of a three word accumulator to represent the number. This accumulator, which is called the floating point accumulator (FAC), is located on page zero in addresses 44_8 to 46_8. The first word contains the exponent with its sign in the zeroth bit. The mantissa is stored in the following two words with the sign of the number in the zeroth bit of the word following the exponent. Numbers requiring three words for storage are defined as "real" within the FORTRAN/8 compiler.

B. CONTROL UNIT

The control unit specifies program flow and is divided into three areas: (1) the program counter; (2) the instruction register; and (3) the major state generator.

The program counter uses a twelve bit register to determine program sequence and indicates the next address from which an instruction will be taken for execution. Unless a branching operation occurs, the program counter is incremented by one each time an instruction is entered into the instruction register.

The instruction register uses a three bit register to hold the operation code of the current instruction. The three bits correspond to bits 0-2 in the address indicated by the program counter.

The major state generator interprets the instruction being executed and sequentially enters one or more of the following states. During the fetch state, an instruction is loaded into the memory buffer

register from core memory at the address indicated by the program counter. The presence of a "1" in bit three of the instruction indicates indirect addressing is required and the defer state is entered. The major state generator then executes the instruction after entering the execute state. Each state requires 1.5 microseconds for execution.

C. MEMORY UNIT

The memory unit consists of a twelve bit memory address register, a twelve bit memory buffer register and a 4096 word magnetic core memory.

The memory address register contains the address of the instruction currently selected for reading or writing. It can also be used to specify the next instruction to be executed. This register is set by either the memory buffer register or the program counter.

The memory buffer register provides a temporary storage location for all words stored into or retrieved from the core memory. In addition, this register is used to update the program counter, set the memory address register and buffer words loaded into the accumulator.

The magnetic core memory is random access. The 4096 words are arranged sequentially with addresses $0\text{-}7777_8$ and divided into thirty-two pages numbered $0\text{-}177_8$. Addresses on page zero and those on the same page as the current instruction can be referenced directly. Addressing between all other pages must be done indirectly.

D. INPUT/OUTPUT UNITS

Input and output devices are combined since many devices serve both functions. The primary input/output device is the teletype with integral paper tape reader/punch. This device accepts and transmits characters in ASCII code which differs from the representation within the computer. Consequently, the computer must convert the characters when data transfers are effected.

The secondary input/output device is the PI-1250-1 data handling system. This is a seven track magnetic tape system designed to operate with the PDP-8 family of computers.

All input and output associated with the PDP-8 computer requires the use of the accumulator. Direct access to the core memory by a peripheral is not possible. In addition, since there is a great difference in the processing speed of the computer and the speed of most peripheral devices, the computer must be programmed to check the readiness of a device prior to attempting the transfer of data.

III. A DESCRIPTION OF THE FORTRAN/8 COMPILER

Construction of the FORTRAN/8 compiler was completed in two stages. The first stage consisted of expressing the FORTRAN/8 grammar in BNF in a form acceptable to the ANALYZER, while the second required major modifications and additions to SKELETON.

The BNF productions for FORTRAN/8 are listed in Appendix A. In general the grammar rules follow those listed in [Ref. 5]. The major exception is in the read/write formats. Due to format complexity and core requirements, the standard FORTRAN read/write formats were abandoned in favor of the simpler but comprehensive formats proposed by Kildall in [Ref. 6]. A listing of FORTRAN constructs allowed by FORTRAN/8 is contained in Appendix B.

Basic design considerations for the second stage were the fast storage/retrieval of data in the FORTRAN/8 compiler and efficient storage utilization in the PDP-8 computer.

Storage utilization became extremely important due to a design requirement that the object module contain the Floating Point Package. This request, coupled with the requirement for supplementary PDP-8 machine language subprograms,[3] reduced the core available by thirty percent. This meant that the program storage within the PDP-8 was limited to 2845 twelve bit words.

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[3]Descriptions of the PDP-8 machine language subprograms are contained in section IV.

The objective for the remainder of this section is to provide a description of the tables and procedures used by the FORTRAN/8 compiler and to provide some details as to how the design goals were achieved.

A. TABLE DESCRIPTIONS

Various tables are referenced for storage and retrieval of data throughout the compiler. This section describes the construction and purposes of the major tables.

1. The Program Reference Table

The program reference table (PRT) contains attributes of variables defined in the program block (subprogram or main program) currently being compiled. This table is divided into three segments:

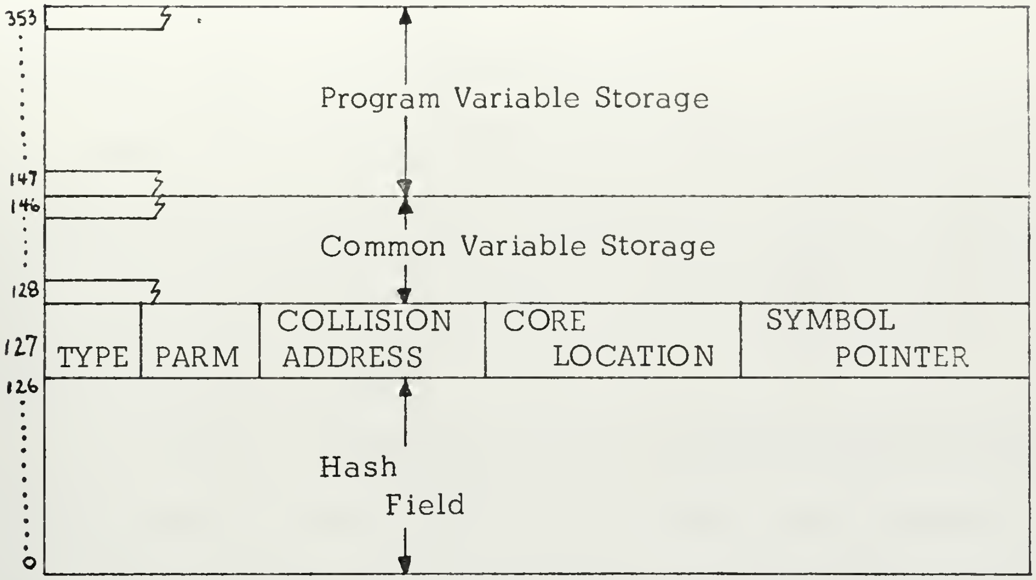
0-126	hash field
127-146	common variable cells
147-353	program variable cells

An explanation of information stored within common and program variable cells is given in Figure 2.

The PRT uses hash coding for the storage and retrieval of variables. Entry to this table is based on the number of characters in the variable name plus the EBCDIC value of the first three characters. The remainder after division by 127 produces the hash code entry to the hash field.

If the location addressed by the hash code entry contains a zero then a pointer to the next available program variable cell (indicated by

THE PROGRAM REFERENCE TABLE



FIELD NAME	BITS	DESCRIPTION
Type	2	0 = integer variable 1 = real variable 2 = integer array 3 = real array
Parm	1	if 1 then the variable is a parameter to the subprogram currently being compiled
Collision	9	a pointer to the variable which collided with the variable occupying this cell
Core Location	12	core address of variable
Symbol	8	pointer to the character representation of the variable in this cell.

FIGURE 2

pointer PT) is entered in the hash field. Variable attributes are then entered in the program variable cell. The variable name is stored in the SYMBOL table (an XPL character array).

Collisions are resolved by placing variable attributes in the next available program variable cell. In this case, however, the pointer to the program variable cell is entered in the collision field of the previously entered variable.

A variable is relocated to the next available common variable cell (indicated by pointer SC) when the variable name is encountered in a COMMON statement. A maximum of twenty variables may be entered into COMMON.

Program variable cells are local to a program block. Consequently, the hash field entries pointing to program variable cells are reset to zero when an END statement is read from the FORTRAN source deck.

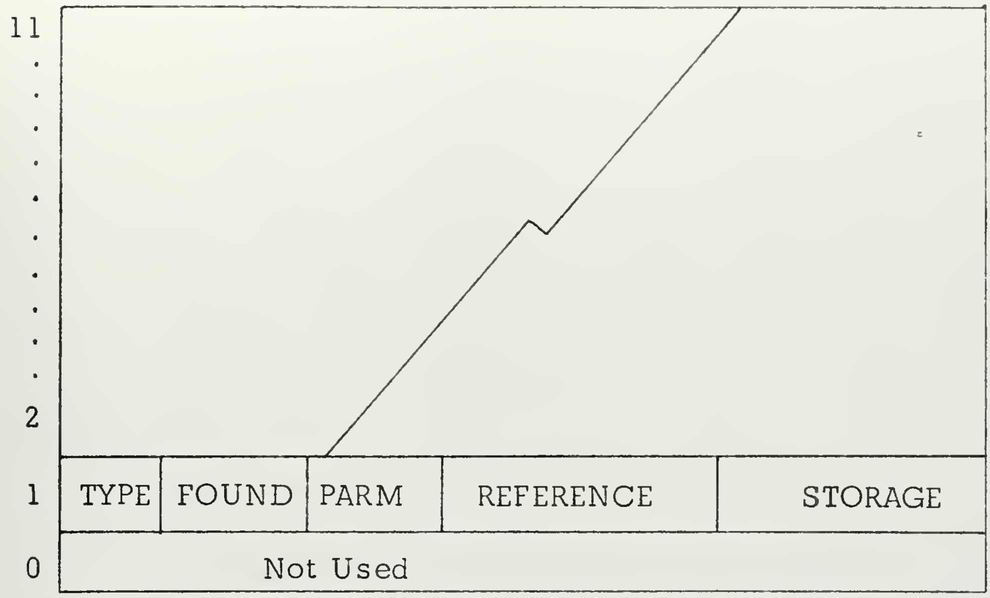
2. <u>PTABLE</u>

The PTABLE contains attributes for the subprograms read from the FORTRAN source deck. Each cell within the table corresponds to one subprogram and has five fields as shown in Figure 3.

The information content of the Type, Found and Parm fields is used by SYNTHESIZE for error analysis purposes, along with decisions concerning the emission of code.

The Reference field refers to an address on page zero of the PDP-8 core. This address contains the location of the beginning (entry) of the subprogram.

PTABLE



FIELD NAME	BITS	DESCRIPTION
Type	3	0 = unknown 1 = function subprogram 2 = subroutine subprogram
Found	1	If this field contains a "1" then the subprogram was included within the source deck at execution time
Parm	4	number of arguments for the subprogram
Reference	12	program variables are passed to the subprogram via locations starting with this address at the top of page zero
Storage	12	program variables are passed to the subprogram via locations starting with this address at the top of page zero

FIGURE 3

Arguments for the subprogram are passed through addresses on page zero. The Storage field contains one of these addresses. The particular address contained in this field is for passing the first argument in the argument list. Succeeding arguments are passed through sequentially lower numbered cells.

The FORTRAN/8 compiler allows a maximum of eleven FORTRAN subprograms. This restriction is due to the limited space on page zero.

3. <u>The LAB Table</u>

The LAB array, shown in Figure 4, contains information concerning labels encountered in the FORTRAN source deck. The table is divided into the following two sections:

0-126 contains the label for a statement and is entered via hash coding

127-255 each cell within this range of the LAB array corresponds to one of the cells between 0 and 126 and contains two pointers. The left 16 bits point to the beginning of the labeled statement while the right 16 bits point to the end of the same statement.

The beginning address is used for such FORTRAN source statements as the GO TO statement. The FORTRAN DO statement requires that both the beginning and the end of a labeled statement be known. The beginning is used for the extent of the loop while the end position is used for branching after completion of the required iterations.

THE LAB TABLE

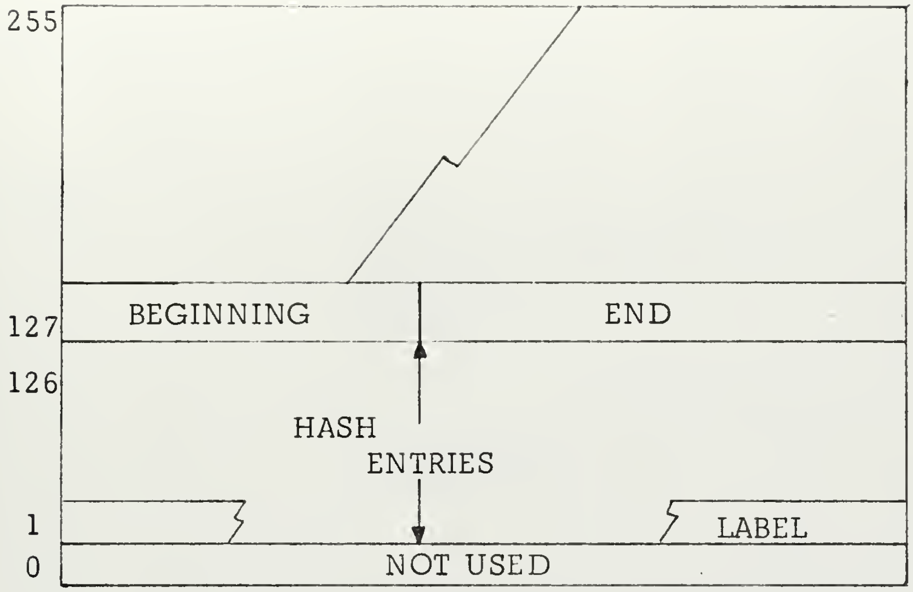


Figure 4

4. <u>The FIXV and FIXM Tables</u>

FIXV is one of several stacks used by the parsing algorithm to store information. As originally intended in SKELETON, FIXV holds a thirty-two bit binary representation of an integer recognized as a terminal symbol by the scanner. If the particular element within the BNF production is not a number then the FORTRAN/8 compiler considers FIXV to be not in use. In this case that position in FIXV is used to hold PRT and PTABLE locations, the number of dimensions for an array or parameters to a subprogram, and a code type for the referenced variable as shown in Figure 5A.

THE FIXV AND FIXM STACKS

PRT or PTABLE Location	Type	Dimension Counter
24 bits	4 bits	4 bits

Type Code		
	0	Function Subprogram
	1	Subroutine Subprogram
	2	Integer Array
	3	Real Array

FIGURE 5A

THE FIXV AND FIXM STACKS

FIXV

Not Used	Exponent
	12 bits

FIXM

Not Used	Mantissa
	24 bits

FIGURE 5B

If an element within a BNF production requires the use of FIXV for number storage then both FIXV and FIXM may receive a portion of the number. The portion each receives is determined by the procedure SCAN. If SCAN does not find a decimal point in the number field then the number value is stored in FIXV as originally intended in SKELETON. However, a decimal point within the number field indicates a real number and three cells are required to store the value into the PDP-8 core memory. In this case FIXV will contain the exponent while FIXM contains the mantissa as shown in Figure 5B.

5. <u>The LOC Stack</u>

The LOC stack is a stack similar to FIXV, and parallels the PARSE_STACK. This stack contains information concerning the core location for expressions, variables, and constants found as elements of a BNF production. The three fields of this stack are shown in Figure 6.

The information content of the LOC stack is used primarily for determining indirect addressing requirements. Indirect addressing is denoted by the presence of a "1" in the address field, and occurs when the expression does not reside on page zero or on the same page as the instructions. The type field contains either a "0" or a "1" which designates that the referenced expression is of type integer or real respectively.

THE LOC STACK

CORE LOCATION	ADDRESS	TYPE
28 bits	2 bits	2 bits

FIGURE 6

THE CODE ARRAY

LABEL	END
16 bits	16 bits

FIGURE 7

THE VCELL_ADDRESS TABLE

CORE LOCATION	PRT LOCATION
16 bits	16 bits

FIGURE 8

6. The CONSTANT1/CONSTANT2 Table

The combination of CONSTANT1 and CONSTANT2 form a table for storage of both integer and real numbers which appear as constants in the FORTRAN source deck (e.g., on the right of an assignment statement). This is a hash coded table whose entries are based on the value of the number. With one exception the configurations of CONSTANT1 and CONSTANT2 correspond to FIXV and FIXM respectively. This exception concerns CONSTANT1. In addition to the exponent stored in FIXV, CONSTANT1 also contains the PDP-8 core address of the referenced constant.

The table is initially loaded with those pre-set constants found on page 0 of the PDP-8 memory map (see Appendix D). Additional entries to the table are effected when:

a. the scanner reads a number from the FORTRAN source deck and

b. the number has not been previously entered in the CONSTANT1/CONSTANT2 table.

The FORTRAN/8 compiler uses the CONSTANT1/CONSTANT2 table to ensure that the same constant will not be given additional storage when it is encountered a second time by SCAN. This is most important in the case of real numbers which require three PDP-8 memory cells to store but only one cell to reference.

7. The CODE Array

The CODE array contains PDP-8 object code. During compilation, this array also contains references to labels. The cells referring to labels are configured as shown in Figure 7. These cells receive the address of either the beginning or end of the labeled statement at the end of each program block.

8. The VCELL_ADDRESS Table

The VCELL_ADDRESS table performs a function similar to the CONSTANT1/CONSTANT2 table. Each cell in this table (see Figure 6) contains the core location and an address on the current page through which that variable has already been accessed. It is through this table that the FORTRAN/8 compiler ensures that a maximum of one reference to a particular variable appears on each PDP-8 memory page.

B. FORTRAN/8 COMPILER ORGANIZATION

The forty-eight procedures for FORTRAN/8 are organized into six main categories: (1) Input; (2) Error; (3) Scan; (4) Initialization; (5) Code Emission; and (6) the Syntactic Parsing Functions. Of the twenty procedures in SKELETON, fifteen were retained with little or no modification. Those procedures modified were: SCAN, INITIALIZATION, ERROR, REDUCE, and SYNTHESIZE.

The relations among the major procedures are listed in Figure 9. Appendix C contains an alphabetic listing of all procedures and the procedures from which they are called.

RELATION AMONG PROCEDURES IN FORTRAN/8

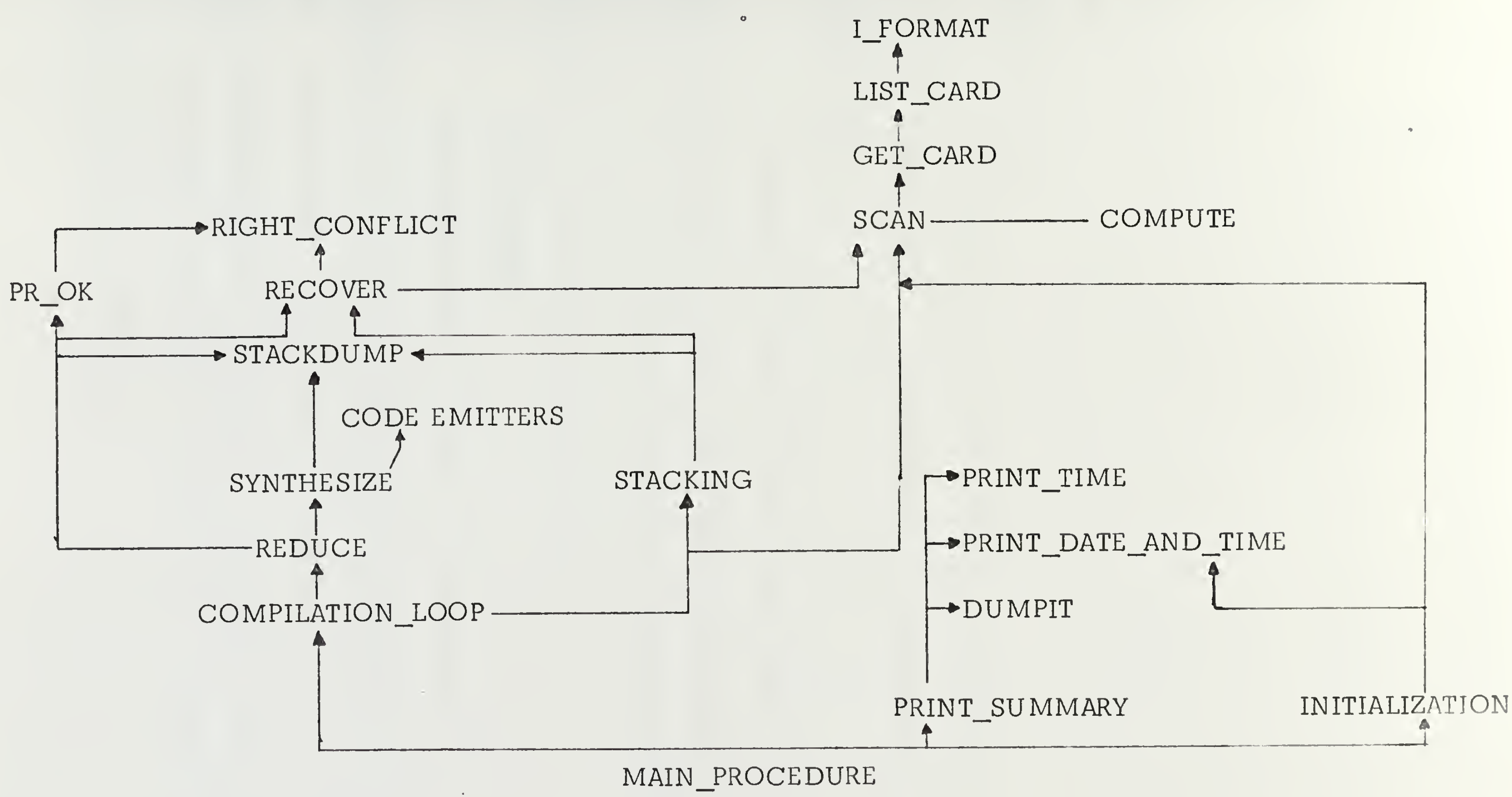


FIGURE 9

The syntactic parsing functions are discussed in detail in [Ref. 1].

1. Error

The error section is composed of procedures I_FORMAT, ERROR, READ_OCTAL and LIST_CARD.

Procedure ERROR prints a mnemonic error message, counts total and severe errors, and terminates the compilation in the case of excessive errors. Procedure I_FORMAT is concerned with the format of the error message.

Procedure READ_OCTAL converts the binary representation of the parameter to octal. This procedure is used primarily for printing the CODE array.

Procedure LIST_CARD holds the card image being processed. Unless an error occurs, the card image will be printed after the statement has been parsed. If an error occurs during the parsing operation, the card image is printed before the error message.

2. Input Section

The input section consists of a single procedure named GET_CARD. This procedure reads the card images of the FORTRAN source deck. The latest card image is held in the character string BUFFER while the following card is in BUFFER1. This allows determination of continuation cards. GET_CARD also adds the ";" required by SCAN to determine the end of a statement.

3. Scan

Scan is composed of two procedures: SCAN and COMPUTE. The only modification to SCAN as it appears in SKELETON was to provide the ability to scan floating point numbers. When the decimal point is found, the number values to the left and right of the decimal point are passed to COMPUTE. COMPUTE converts the fractional decimal representation of the scanned real number to exponential form for COMPILATION_LOOP to insert into FIXV and FIXM.

4. Initialization

The initialization section consists of one procedure called INITIALIZATION. This procedure:

a. sets the global constants;

b. inserts PDP-8 page zero entries into the code array;

c. inserts the PDP-8 machine language subprograms into the CODE array; and

d. loads a jump indirect instruction into core location 200_8.

The jump instruction allows the user to place FORTRAN subprograms before the main program and ensures that execution of the PDP-8 program will always commence at address 200_8. Just prior to the return from INITIALIZATION, the PDP-8 memory map is configured as shown in Appendix D.

5. Code Emission

The code emission section consists of twenty-six procedures whose relationships are shown in Figure 10. SYNTHESIZE[4] is the driving procedure in this section. The remaining procedures can be separated into the following six categories: (1) procedures concerning FORTRAN subprograms; (2) the subscripting of variables; (3) control of simple variables; (4) the referencing of labels; (5) the assignment of temporary cells; and (6) the procedures for code emission.

a. Procedures Concerning FORTRAN Subprograms

Contrary to most FORTRAN compilers, FORTRAN/8 permits the placing of FORTRAN subprograms both before and after the main program. The starting address for each subprogram is listed on page zero (see Appendix D) and addressed indirectly. SET_PROC obtains an address for indirectly addressing the procedure from GET_PCELL and places the initial values in PTABLE. Cells for passing parameters are taken from the top of page zero and the variable PARMCELL tallies the usage of these cells. FIND_PROC locates a procedure already entered in PTABLE.

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[4] In order to understand how SYNTHESIZE passes information from one reduction to another, the user must familiarize himself with the system of flags (shown in Figure 11) and the stacks described in [Ref. 1].

RELATION AMONG PROCEDURES CALLED BY SYNTHESIZE

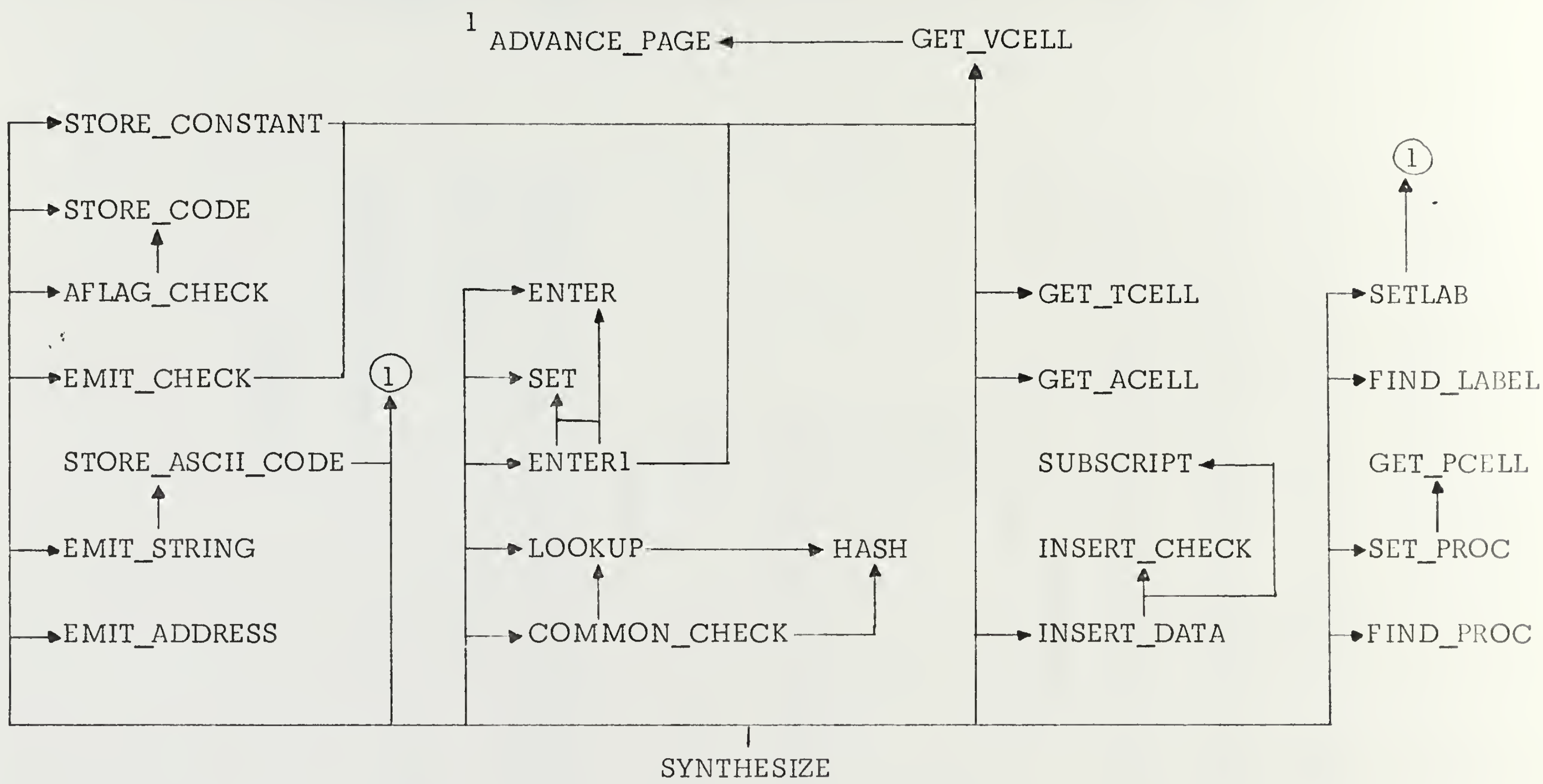

FIGURE 10

FLAGS USED IN FORTRAN/8

CODE EMISSION SECTION

AFLAG	if set (1) then real expressions are currently being processed and the Floating Point accumulator is in use
CFLAG	if set (1) then the FORTRAN statement being compiled is a subroutine call.
DFLAG	used for dimension, declaration and common statements

Value	Description
0	INTEGER
1	REAL
2	DIMENSION
3	into main body of subprogram or main program
4	DATA
5	COMMON

RFLAG	checks to ensure at least one RETURN statement is inside the FORTRAN subprogram body. If set (1) when reaching an END statement then no RETURN statement was included within the subprogram
SFLAG	if set (1) then currently processing a FORTRAN subprogram, else 0

FIGURE 11

b. The Subscripting of Variables

Storage for subscripted variables is obtained from procedure GET_ACELL on the basis of the number of dimensions, whether the variable is declared real or integer, and the extent of each dimension for the variable. The number of cells assigned by GET_ACELL for storage of the subscripted variable is determined by the following formula:

if subscripted array is of type real

then T = 3

otherwise T = 1

n = number of dimensions

r_i = extent of the i^{th} dimension

$$\text{cells assigned} = n + 1 + T\left(\prod_{i=1}^{n} r_i\right)$$

Storage for these cells is obtained from page 26_8 starting at address 5435_8. Succeeding cells are taken from sequentially lower numbered core addresses. Figure 12 shows an example of storage for both an integer array(I) and a real array (R).

The address of a particular element of a subscripted variable is computed using the following formula:

n = number of dimensions

u_i = size of the i^{th} dimension

$$D_i = \begin{cases} \text{if } i = n \text{ then } 1 \text{ (3 fo real array)} \\ \text{otherwise } u_{i+1} \; D_{i+1} \end{cases}$$

r_i = extent of the i^{th} dimension

L = base of array storage block

$$\text{address} = \sum_{i=1}^{n} r_i D_i - \sum_{i=1}^{n} D_i + L + n + 1$$

The values for D_1 through D_{n-1} and $\sum D_i$'s are stored in the array storage block as well as a negative number which represents the number of dimensions.[5] These values are used at compile time by procedures INSERT_DATA and SUBSCRIPT to insert initial values into the subscripted variables.

c. Control of Simple Variables

Procedures ENTER and ENTER1 place the variable names and attributes in the PRT. ENTER1 also calls procedure SET to determine the variable's type according to the standard FORTRAN rules. If the first letter of the variable is I,J,K,L,M, or N then the variable is typed as an integer and requires one cell for storage. Otherwise, the

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[5] The dimensions are stored in negative form due to the PDP-8 machine instructions and the manner in which subscripting is done at execute time.

PDP-8 Memory Map

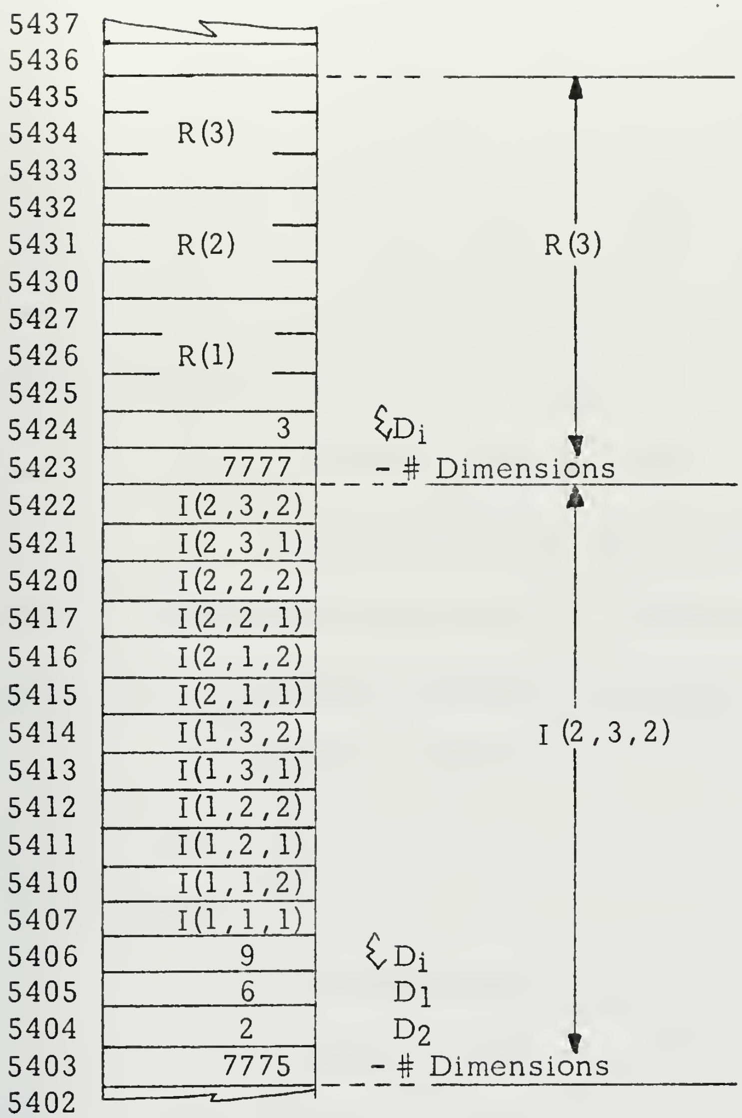

FIGURE 12

variable is typed as a real and requires three cells. The storage cells for simple variables are obtained from the procedure GET_VCELL and are called VCELLs. GET_VCELL provides these cells from the top of the page currently being loaded with instructions.

The procedure LOOKUP is used to locate a variable in the PRT. Entries to the hash field of the PRT are obtained from procedure HASH. Finally, COMMON_CHECK relocates a variable within the PRT from a program variable cell to a common cell when the variable name is contained in a common statement.

d. The Referencing of Labels

The beginning and end of each labeled statement are saved within the procedure FIND_LAB. Procedure SETLAB calls GET_VCELL and sets the returned VCELL so that the referenced label can be reset at the end of the program block. An error message will be printed if the referenced label is not located by the time the scanner reaches an END statement.

e. The Assignment of Temporary Cells

Temporary cells are located on page 0 between addresses 76_8 and 177_8 and are called TCELLs. Procedure GET_TCELL competes with PARMCELL for access to this area of the PDP-8 memory. Any overlap between TCELL and PARMCELL will require the FORTRAN statement to be separated into two or more statements or the number of subprogram parameters to be reduced. All TCELLs become available for assignment at the beginning of each FORTRAN statement.

f. The Procedure for Code Emission

Procedure STORE_CODE inserts the PDP-8 instructions into the CODE array starting at address 202_8. As the code generation approaches the VCELLs in use on the same page, procedure ADVANCE_PAGE will emit a jump to the following page. ADVANCE_PAGE will also ensure that the Floating Point Package is exited prior to and reset after the jump.

The procedure EMIT_CHECK determines if the referenced expression must be indirectly addressed. A VCELL is used for indirect addressing if the constant or variable is assigned off the page on which instructions are currently being inserted. The requirement for indirect addressing is determined from CONSTANT1, LOC, or the absence of the variable in the VCELL_ADDRESS table.

Procedure STORE_CONSTANT obtains storage from GET_VCELL and inserts the constant into these cells. It also updates the CONSTANT1/CONSTANT2 table.

Frequently addresses must be passed as parameters to one of the PDP-8 machine language subprograms. These addresses follow the jump instruction to the subprogram. Procedure EMIT_ADDRESS ensures that the required addresses are loaded after the jump.

The process of inserting of character strings into the CODE array is accomplished by procedure EMIT STRING. This procedure uses the procedure STORE_ASCII_CODE to convert the IBM EBCDIC

character representation to ASCII code. A listing of the ASCII code characters available to FORTRAN/8 users is contained in Appendix E.

C. FORTRAN/8 LISTINGS

The listing produced by the FORTRAN/8 compiler includes each card image from the source deck and any error messages which occurred during compilation. Additions to this listing can be effected by the use of the control cards which are described in Appendix G.

IV. FORTRAN/8 OBJECT MODULE

The generation of the object module (defined as the CODE array in FORTRAN/8) begins in the procedure INITIALIZATION. Before entering page zero references however, the content of each address in the CODE array is set to zero. Therefore, PDP-8 users are assured that the content of each address in a subscripted variable is zero at execution time. PDP-8 machine language subprograms, which appear in the declarations of FORTRAN/8, are then loaded into the CODE array.

A. PDP-8 INSTRUCTION SET

Two types of instructions[6] are available for the PDP-8: memory reference, and augmented. The memory reference instructions are used to store and retrieve information from core memory, while the augmented instructions accomplish specialized tasks. The operation code of both types is specified in the left most three bits (positions 0-2) of the twelve bit word.

1. Memory Reference Instructions

Memory reference instructions are designated by operation codes zero through five. These instructions use the right most seven

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[6] A listing of the PDP-8 instructions used by FORTRAN/8 is contained in Appendix H.

bits (positions 5-11) as an address field and a direct reference can be made to any location on the current page or page zero. If bit three contains a "1" then the address field refers to the current page, otherwise it refers to page zero.

2. Augmented Instructions

There are two augmented instructions: input/output transfer (operation code six) and operate (operation code seven). Both augmented instructions can be microprogrammed to perform several sequential operations by the setting of bits three through eleven. Neither of these instructions accesses core memory.

The input/output transfer instruction initiates the operation of peripheral equipment and effects information transfers between the arithmetic unit and an I/O device.

Operate instructions are divided into Group 1 and Group 2. The first group is principally for clear, complement, rotate and increment operations. The presence of a "1" in bit three designates Group 2 instructions which check the accumulator and perform skipping operations based on this check.

B. PDP-8 SUBPROGRAMS

Ten of the eleven subprograms loaded into the object module will be covered in this section.[7] The eleventh, the Floating Point Package and corelated Input/Output subprograms, are covered in [Ref. 5].

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[7] Appendix I contains address sequential listings of the ten subprograms

1. I/O Subprograms

WRITE_STRING emits a continuous string of ASCII characters to the teletype. These characters are read from the addresses following the jump subroutine instruction (JMS). A return to the program is accomplished by reading a WEXT instruction.

TAB returns the teletype carriage and then advances the carriage a number of spaces equal to the value found following the keyword TAB in the FORTRAN source deck.

The transmission of integer numbers is handled in the INTEGER_READ and INTEGER_WRITE subprograms. The argument for these subprograms is the address of the expression to be transferred. The Input/Output subprograms associated with the Floating Point Package and the floating point accumulator are used to complete the transfer. As a result, all numbers will be printed on the teletype in exponential form.

2. Subscripts

All execution time subscript calculations are handled in the ARRAY_SUBSCRIPTOR subprogram. The subscripts for the desired variable are loaded into page zero addresses 0063_8 -0065_8 prior to the JMS instruction. The last subscript is always entered in 0063_8 and is negative if that variable is declared real. The ARRAY_SUBSCRIPTOR returns the calculated address.

3. Arithmetic Operations

MULTIPLY and DIVIDE are used for integer multiplication and division operations. Both subprograms operate on the two addresses

following the JMS instruction and return the calculated value. MULTIPLY works on the principle of successive addition while DIVIDE works with successive subtraction.

EXPONENTIATION also operates on the two addresses following the JMS instruction. The first address is treated as the exponent and must refer to an integer expression. The second address is the number to be exponentiated and this address must refer to a real expression. The result is returned in the floating point accumulator.

FLOAT converts an integer expression to a real expression and places the result in three TCELLs.

V. CONCLUSIONS

The PDP-8 is an extremely versatile computer with considerable potential. It was found relatively easy to program and possesses a considerable inventory of usable instructions.

Several FORTRAN source decks were tested on the FORTRAN/8 compiler. The most comprehensive of these decks totaled sixty-three cards. This deck was compiled in approximately two seconds of CPU time. The object module (discounting page zero entries, PDP-8 machine language subroutines, and the storage area required for subscripted variables) required approximately twelve PDP-8 words for each source deck card. Based on this figure and the amount of usable core, it is estimated that the PDP-8 could handle a source deck exceeding 200 cards.

Implementation of the FORTRAN/8 compiler at the Naval Postgraduate School completed the first of two phases to provide PDP-8 users with the capability to test FORTRAN programs. The second phase will consist of constructing a PDP-8 simulator on the IBM System 360. This simulator will accept the object module produced by FORTRAN/8 and provide users with a complete package for the testing and running of FORTRAN programs when the PDP-8 system is not available.

APPENDIX A.

BNF FOR FORTRAN/8

```
 1   <MASTER PROGRAM>  ::= <PROGRAM>

 2   <PROGRAM>  ::=  <STATEMENT BLOCK> END ;
                 |   <PROGRAM> <STATEMENT BLOCK> END ;

 4   <STATEMENT BLOCK>  ::=  <STATEMENT LIST>
 5                        |  <DECLARATION LIST> <STATEMENT LIST>
 6                        |  <PROCEDURE BLOCK> <STATEMENT LIST>

 7   <STATEMENT LIST>  ::=  <STATEMENT> ;
 8                      |   <STATEMENT LIST> <STATEMENT> ;

 9   <STATEMENT>  ::=  <IF STATEMENT>
10                 |   <BASIC STATEMENT>
11                 |   <DO STATEMENT>
12                 |   <LABELED STATEMENT>

13   <BASIC STATEMENT>  ::=  <ASSIGNMENT STATEMENT>
14                        |  <GO STATEMENT>
15                        |  <SUBROUTINE CALL>
16                        |  <READ STATEMENT>
17                        |  <WRITE STATEMENT>
18                        |  RETURN
19                        |  STOP

20   <IF STATEMENT>  ::=  <ARITHMETIC IF> <DOUBLE LABEL> <NUMBER>
21                    |   <LOGICAL IF> <BASIC STATEMENT>

22   <ARITHMETIC IF>  ::=  <IF> <EXPRESSION>

23   <IF>  ::=  IF (

24   <DOUBLE LABEL>  ::=  ) <LABEL1> <LABEL1>

25   <LABEL1>  ::=  <NUMBER> ,

26   <EXPRESSION>  ::=  <TERM>
27                   |  <EXPRESSION> + <TERM>
28                   |  <EXPRESSION> - <TERM>
29                   |  + <TERM>
30                   |  - <TERM>

31   <TERM>  ::=  <PRIMARY>
```

```
32                    |  <PRIMARY*> <PRIMARY>
33                    |  <TERM> / <PRIMARY>

34    <PRIMARY>  ::=   <SECONDARY>
35                 |   <PRIMARY*> * <SECONDARY>

36    <PRIMARY*>  ::=  <SECONDARY>  *

37    <SECONDARY>  ::=  <VARIABLE>
38                   |  <NUMBER>
39                   |  ( <EXPRESSION> )
40                   |  ABS ( <EXPRESSION> )
41                   |  SQR ( <EXPRESSION> )
42                   |  SQRT ( <EXPRESSION> )
                     |  FLOAT ( <EXPRESSION> )

43    <LOGICAL IF>  ::=  <IF> <BOOLEAN EXPRESSION> )

44    <BOOLEAN EXPRESSION>  ::=  <BOOLEAN TERM>
45                            |  <BOOLEAN EXPRESSION> .OR. <BOOLEAN TERM>

46    <BOOLEAN TERM>  ::=  <BOOLEAN PRIMARY>
47                      |  .NOT. <BOOLEAN PRIMARY>
48                      |  <BOOLEAN TERM> .AND. <BOOLEAN PRIMARY>

49    <BOOLEAN PRIMARY>  ::=  <LOGICAL EXPRESSION>
50                         |  ( <BOOLEAN EXPRESSION> )

51    <LOGICAL EXPRESSION>  ::=  <EXPRESSION> <RELATION> <EXPRESSION>

52    <RELATION>  ::=  .LT.
53                  |  .LE.
54                  |  .EQ.
55                  |  .NE.
56                  |  .GT.
57                  |  .GE.

58    <LABELED STATEMENT>  ::=  <LABEL2> <STATEMENT>
59                           |  <LABEL2> CONTINUE

60    <LABEL2>  ::=  <NUMBER>

61    <ASSIGNMENT STATEMENT>  ::=  <VARIABLE> <RIGHT PART>

62    <RIGHT PART>  ::=  = <EXPRESSION>
                      |  = <VARIABLE> <RIGHT PART>

64    <VARIABLE>  ::=  <IDENTIFIER>
```

```
65                    |  <SUBSCRIPT HEAD> <EXPRESSION> )

66   <SUBSCRIPT HEAD>  ::=  <IDENTIDIER>  (
67                       |  <SUBSCRIPT HEAD> <EXPRESSION> ,

68   <DO STATEMENT>  ::=  <DO HEAD>
69                     |  <DO HEAD> , <EXPRESSION>

70   <DO HEAD>  ::=  <DO VARIABLE> , <EXPRESSION>

71   <DO VARIABLE>  ::=  <DO LABEL> <VARIABLE> = <EXPRESSION>

72   <DO LABEL>  ::=  DO <NUMBER>

73   <GO STATEMENT>  ::=  <GOTO> <NUMBER>
74                     |  <GO TRANSFER> <END GO> <VARIABLE>

75   <GOTO>  ::=  GO TO
76             |  GOTO

77   <GO TRANSFER>  ::=  <GOTO> <PAREN> <NUMBER>
78                    |  <GO TRANSFER> <COMMA> <NUMBER>

79   <PAREN>  ::=  (

80   <COMMA>  ::=  ,

81   <END GO>  ::=  ) ,

82   <DECLARATION LIST>  ::=  <DECLARATION> ;
83                         |  <DECLARATION LIST> <DECLARATION> ;

84   <DECLARATION>  ::=  <DECLARATION TYPE> <VARIABLE>
85                    |  <DECLARATION TYPE> <VARIABLE LIST> <VARIABLE>
86                    |  <DATA DECLARATION> <NUMBER> /

87   <DECLARATION TYPE>  ::=  DIMENSION
88                         |  INTEGER
89                         |  REAL
90                         |  COMMON

91   <VARIABLE LIST>  ::=  <VARIABLE> ,
92                      |  <VARIABLE LIST> <VARIABLE> ,

93   <DATA DECLARATION>  ::=  <DATA HEAD> /
94                         |  <DATA DECLARATION> <NUMBER> ,

95   <DATA HEAD>  ::=  <DATA> <VARIABLE>
```

```
96                     |  <DATA> <VARIABLE LIST> <VARIABLE>

97   <DATA>  ::=  DATA

98   <PROCEDURE BLOCK>  ::=  <PROCEDURE HEADING>
99                        |  <PROCEDURE HEADING> <DECLARATION LIST>

100  <PROCEDURE HEADING>  ::=  <PARAMLESS PROCEDURE>
101                         |  <PROCEDURE & PARAMETERS>

102  <PARAMLESS PROCEDURE>  ::=  SUBROUTINE <IDENTIFIER>  ;

103  <PROCEDURE & PARAMETERS>  ::=  <PROCEDURE HEAD> <IDENTIFIER> ) ;

104  <PROCEDURE HEAD>  ::= <PROCEDURE TYPE>
105                     |  <PROCEDURE HEAD> <IDENTIFIER> ,

106  <PROCEDURE TYPE>  ::=  FUNCTION <IDENTIFIER>  (
107                     |   SUBROUTINE <IDENTIFIER>  (

108  <SUBROUTINE CALL>  ::=  <CALL> <VARIABLE>

109  <CALL>  ::=  CALL

110  <READ STATEMENT>  ::=  <READ HEAD> <VARIABLE>  )

111  <READ HEAD>  ::=  READ (
112                 |  <READ HEAD> <VARIABLE> ,

113  <WRITE STATEMENT>  ::=  <WRITE HEAD> <EXPRESSION> )
114                       |  <WRITE HEAD> <STRING> )
115                       |  <WRITE HEAD> <TAB EXPRESSION> )

116  <WRITE HEAD>  ::=  WRITE (
117                  |  WRITEON (
118                  |  <WRITE HEAD> <EXPRESSION> ,
119                  |  <WRITE HEAD> <STRING> ,
120                  |  <WRITE HEAD> <TAB EXPRESSION> ,

121  <TAB EXPRESSION>  ::=  TAB <EXPRESSION>
```

APPENDIX B

FORTRAN STATEMENTS ALLOWED IN FORTRAN/8

Statement Type	Example	Semantics
Integer Declaration	INTEGER Z,ARRAY(2,4,3),D	for numbers between -2047 and +2047 subscripts must be integer numbers
Real Declaration	REAL I,MATRIX(10,10,10)	values stored in exponential form values can be used as integers for numbers between $\pm 10^{\pm 15}$ subscripts must be integer numbers
Dimension	DIMENSION LOW(4,3),R(2)	cell allocation based on A-H,O-Z being real (3 cell) I-N being integer (1 cell) maximum of three subscripts allowed
COMMON	COMMON LOW, Z, ARRAY	position within COMMON statement of no relevance common variables must always be referenced by the same name once variable is in COMMON, it must not be reentered in a succeeding program block
DATA	DATA R(1),I,R(2)/0.5,4,1.0/	

Statement Type	Example	Semantics
Assignment	A=B M1=M2=M3=M4 A=M1 (not allowed)	triple assignments allowable no mixed assignments
Unconditional Go To	GO TO 50 GOTO 50	
Computed Go To	GO TO $(n_i, \ldots, n_m)$, I	no limit to number of labels n_i conditional variable (I) must be of integer type
Arithmetic If	IF (e) n_1, n_2, n_3	expression (e) may be real or integer
Logical If	IF ((A.GE.B).OR.(I.LT.J) STOP	expressions flanking .GT., .LT.,.GE.,.LE.,.NE. and .EQ. must be of same type
Do	DO n v = m_1, m_2 DO n v = m_1, m_2, m_3	variable v may be real or integer and the type of m_1, m_2 and m_3 must correspond to v
Continue	CONTINUE	each nested DO statement must end on a different labeled statement or CONTINUE
Stop	STOP	
End	END	

Statement Type	Example	Semantics
Subroutine Call	CALL LARGE (ARRAY,X,Y)	
Subroutine	SUBROUTINE LARGE (A,B,C)	
Parameter Less Subroutine	SUBROUTINE BIG	
Function	FUNCTION SMALL (A,B,C)	returns value assigned to function name, therefore SMALL must appear on left of an assignment statement within function body
Return	RETURN	
Read	READ (ARRAY (i,j),Z)	reads one value at a time from teletype
Write	WRITE (ARRAY (i,j),Z)	writes one value at a time from teletype writes all values within the write field on the same line
Writeon	WRITEON (M,A,LOW (i,j))	same as Write except continues writing on same line
Tab	WRITE (A,TAB 20,B)	writes A against left margin of teletype, B will then be written starting in column 20

Macroprograms	Semantics
ABS(e)	absolute value for either real or integer expressions
SQRT(e)	square root for real expressions only
SQR(e)	square for real expressions only
FLOAT(e)	converts an integer expression to a real expression

APPENDIX C

FORTRAN/8 PROCEDURE LISTING

PROCEDURES	CALLED BY
ADVANCE_PAGE *	GET_VCELL SETLAB STORE_CODE STORE_ASCII_CODE SYNTHESIZE
AFLAG_CHECK *	SYNTHESIZE
COMMON_CHECK	SYNTHESIZE
COMPILATION_LOOP	MAIN_PROCEDURE
COMPUTE	SCAN
DUMP	SYNTHESIZE
DUMPING	DUMP
DUMPIT	PRINT_SUMMARY
EMIT_ADDRESS *	SYNTHESIZE
EMIT_CHECK *	SYNTHESIZE
EMIT_STRING *	SYNTHESIZE
ENTER	ENTER1 SYNTHESIZE
ENTER1	SYNTHESIZE

*Code emitting procedures

PROCEDURES	CALLED BY
ERROR	COMMON_CHECK COMPILATION_LOOP COMPUTE EMIT_STRING ENTER FIND_LABEL GET_PCELL GET_TCELL INSERT_CHECK REDUCE SCAN STACKING SYNTHESIZE
FIND_LABEL	SYNTHESIZE
FIND_PROC	SYNTHESIZE
GET_ACELL	SYNTHESIZE
GET_CARD	SCAN
GET_PCELL	SET_PROC
GET_TCELL	SYNTHESIZE
GET_VCELL	EMIT_CHECK ENTER1 SETLAB STORE_CONSTANT SYNTHESIZE
HASH	COMMON_CHECK ENTER LOOKUP
I_FORMAT	LIST_CARD
INITIALIZATION *	MAIN_PROCEDURE
INSERT_CHECK	INSERT_DATA
INSERT_DATA *	SYNTHESIZE

PROCEDURES	CALLED BY
LIST_CARD	ERROR GET_CARD
LOOKUP	COMMON_CHECK DUMPING SYNTHESIZE
MAIN_PROCEDURE	Initial Call
PR_OK	REDUCE
PRINT_DATE_AND_TIME	INITIALIZATION PRINT_SUMMARY
PRINT_SUMMARY	
PRINT_TIME	PRINT_DATE_AND_TIME PRINT_SUMMARY
READ_OCTAL	DUMPING LIST_CARD SYNTHESIZE
RECOVER	REDUCE STACKING
REDUCE	COMPILATION_LOOP STACK_DUMP
RIGHT_CONFLICT	PR_OK RECOVER
SCAN	COMPILATION_LOOP INITIALIZATION RECOVER
SET	ENTER1 SYNTHESIZE
SETLAB *	SYNTHESIZE
SET_PROC	SYNTHESIZE

PROCEDURES	CALLED BY
STACKING	COMPILATION_LOOP
STACK_DUMP	STACKING
STORE_ASCII_CODE	EMIT_STRING
STORE_CODE *	AFLAG_CHECK EMIT_CHECK SYNTHESIZE
STORE_CONSTANT *	SYNTHESIZE
SUBSCRIPT	INSERT_DATA
SYNTHESIZE *	REDUCE

APPENDIX D

PDP-8 MEMORY MAP

Page 0

177	Temporaries	
176		
76		
75	7730	Exponential Subprogram
74	0000	Floating Point 0.0 (74–72)
73	0000	
72	0000	Floating Point -1.0 (72–70)
71	6000	
70	0001	
67	7674	Divide Subprogram
66	7652	Multiply Subprogram
65	0000	For Subscripting Arrays (65–63)
64	0000	
63	0000	
62	7600	Subscript Subprogram
61	Registers for Floating Point Package	
40		
37	5563	Integer Read Subprogram
36	5530	Integer Write Subprogram
35	5514	Write String Subprogram
34	5474	Tab Subprogram
33	5435	Float Subprogram
32		Addresses for indirectly Addressing the FORTRAN subprograms
20		
17	Auto Indexing	
10		
7	5600	Floating Point Intrepter
6	7400	Floating Point Input
5	7200	Floating Point Output
4	0001	Fixed Point 1
3	0002	Fixed Point 2
2	7777	Fixed Point -1
1	For Program Interrupts	
0		

Pages 1-37_8

7777 7756	Rim Loader
7730	Exponentiation Subprogram
7674	Divide Subprogram
7652	Multiply Subprogram
7600	Subscript Subprogram
5600	Floating Point Package
5563	Integer Read Subprogram
5530	Integer Write Subprogram
5514	Write_String Subprogram
5474	Tab Subprogram
202	Code Generated By FORTRAN/8 Compiler
201	Address of main program
200	JMP I 201

APPENDIX E

ASCII CODE

Character	Code
A	301
B	302
C	303
D	304
E	305
F	306
G	307
H	310
I	311
J	312
K	313
L	314
M	315
N	316
O	317
P	320
Q	321
R	322
S	323
T	324
U	325
V	326
W	327
X	330
Y	331
Z	332
0	260
1	261
2	262
3	263
4	264
5	265
6	266
7	267
8	270
9	271

Character	Code	
!	241	note 1
"	242	note 2
#	243	
$	244	
%	245	
&	246	
'	247	
(	250	
)	251	
*	252	
+	253	
,	254	
-	255	
.	256	
/	257	
:	272	
;	273	
<	274	
=	275	
>	276	
?	277	
@	300	
Line Feed	212	
Return	215	
Space	240	

Note 1: explanation mark available as " ¬ " (11-7-8 Punch)

Note 2: double quote available as " | " (12-7-8 Punch)

APPENDIX F

THE FORTRAN/8 COMPILER

```
DECLARE NSY LITERALLY '105', NT LITERALLY '47';
DECLARE V(NSY) CHARACTER INITIAL ( '<ERROR: TOKEN = 0>', ';', '(', ')', ',',
   '+', '-', '/', '*', '=', 'IF', 'DO', 'GO', 'TO', '_|_', 'END', 'ABS',
   'SQR', 'TAB', 'STOP', 'SQRT', '.OR.', '.LT.', '.LE.', '.EQ.', '.NE.',
   '.GT.', '.GE.', 'GOTO', 'REAL', 'DATA', 'CALL', 'READ', 'FLOAT', '.NOT.',
   '.AND.', 'WRITE', 'RETURN', 'COMMON', 'INTEGER', 'WRITEON', '<NUMBER>',
   'CONTINUE', 'FUNCTION', '<STRING>', 'DIMENSION', 'SUBROUTINE',
   '<IDENTIFIER>', '<IF>', '<TERM>', '<GOTO>', '<DATA>', '<CALL>', '<PAREN>',
   '<COMMA>', '<LABEL1>', '<LABEL2>', '<END GO>', '<PROGRAM>', '<PRIMARY>',
   '<DO HEAD>', '<PRIMARY*>', '<VARIABLE>', '<RELATION>', '<DO LABEL>',
   '<STATEMENT>', '<SECONDARY>', '<DATA HEAD>', '<READ HEAD>',
   '<LOGICAL IF>', '<EXPRESSION>', '<RIGHT PART>', '<WRITE HEAD>',
   '<DO VARIABLE>', '<GO TRANSFER>', '<DECLARATION>', '<IF STATEMENT>',
   '<DO STATEMENT>', '<GO STATEMENT>', '<DOUBLE LABEL>', '<BOOLEAN TERM>',
   '<ARITHMETIC IF>', '<VARIABLE LIST>', '<MASTER PROGRAM>',
   '<STATEMENT LIST>', '<READ STATEMENT>', '<SUBSCRIPT HEAD>',
   '<PROCEDURE HEAD>', '<PROCEDURE TYPE>', '<TAB EXPRESSION>',
   '<STATEMENT BLOCK>', '<PROCEDURE BLOCK>', '<BASIC STATEMENT>',
   '<SUBROUTINE CALL>', '<WRITE STATEMENT>', '<BOOLEAN PRIMARY>',
   '<DECLARATION LIST>', '<DECLARATION TYPE>', '<DATA DECLARATION>',
   '<LABELED STATEMENT>', '<PROCEDURE HEADING>', '<BOOLEAN EXPRESSION>',
   '<LOGICAL EXPRESSION>', '<PARAMLESS PROCEDURE>', '<ASSIGNMENT STATEMENT>',
   '<PROCEDURE & PARAMETERS>');
DECLARE V_INDEX(12) BIT(8) INITIAL ( 1, 10, 14, 19, 33, 37, 39, 41, 45, 46,
   47, 47, 48);
DECLARE C1(NSY) BIT(96) INITIAL (
   "(2) 00000 00000 00000 00000 00000 00000 00000 00000 00000 000",
   "(2) 00000 00000 22202 20002 00000 00022 22200 02222 22020 222",
   "(2) 00300 33000 00000 03320 30000 00000 00033 00000 03002 003",
   "(2) 03023 22222 00200 00002 02222 22220 02200 22200 21000 002",
   "(2) 00300 33000 00000 03320 30000 00000 00030 00000 03002 003",
   "(2) 00100 00000 00000 01100 10000 00000 00010 00000 01000 001",
   "(2) 00100 00000 00000 01100 10000 00000 00010 00000 01000 001",
   "(2) 02100 00000 00000 01100 10000 00000 00010 00000 03000 001",
   "(2) 00300 00020 00000 03300 30000 00000 00030 00000 03000 003",
   "(2) 00100 11000 00000 01100 10000 00000 00010 00000 01000 001",
   "(2) 00100 00000 00000 00000 00000 00000 00000 00000 00000 000",
   "(2) 00000 00000 00000 00000 00000 00000 00000 00000 01000 000",
   "(2) 00000 00000 00010 00000 00000 00000 00000 00000 00000 000",
   "(2) 00200 00000 00000 00000 00000 00000 00000 00000 02000 000",
   "(2) 00000 00000 11100 00001 00000 00011 11100 01111 11010 111",
   "(2) 01000 00000 00000 00000 00000 00000 00000 00000 00000 000",
   "(2) 00100 00000 00000 00000 00000 00000 00000 00000 00000 000",
```

```
"(2) 00100 00000 00000 00000 00000 00000 00000 00000 00000 000",
"(2) 00100 11000 00000 01100 10000 00000 00010 00000 01000 001",
"(2) 02000 00000 00000 00000 00000 00000 00000 00000 00000 000",
"(2) 00100 00000 00000 00000 00000 00000 00000 00000 00000 000",
"(2) 00100 11000 00000 01100 10000 00000 00011 00000 01000 001",
"(2) 00200 22000 00000 02200 20000 00000 00020 00000 02000 002",
"(2) 00200 22000 00000 02200 20000 00000 00020 00000 02000 002",
"(2) 00200 22000 00000 02200 20000 00000 00020 00000 02000 002",
"(2) 00200 22000 00000 02200 20000 00000 00020 00000 02000 002",
"(2) 00200 22000 00000 02200 20000 00000 00020 00000 02000 002",
"(2) 00200 22000 00000 02200 20000 00000 00020 00000 02000 002",
"(2) 00200 00000 00000 00000 00000 00000 00000 00000 02000 000",
"(2) 00000 00000 00000 00000 00000 00000 00000 00000 00000 002",
"(2) 00000 00000 00000 00000 00000 00000 00000 00000 00000 002",
"(2) 00000 00000 00000 00000 00000 00000 00000 00000 00000 002",
"(2) 00100 00000 00000 00000 00000 00000 00000 00000 00000 000",
"(2) 00100 00000 00000 00000 00000 00000 00000 00000 00000 000",
"(2) 00100 11000 00000 01100 10000 00000 00010 00000 01000 001",
"(2) 00100 11000 00000 01100 10000 00000 00010 00000 01000 001",
"(2) 00100 00000 00000 00000 00000 00000 00000 00000 00000 000",
"(2) 02000 00000 00000 00000 00000 00000 00000 00000 00000 000",
"(2) 00000 00000 00000 00000 00000 00000 00000 00000 00000 002",
"(2) 00000 00000 00000 00000 00000 00000 00000 00000 00000 002",
"(2) 00100 00000 00000 00000 00000 00000 00000 00000 00000 000",
"(2) 02023 22320 22200 00002 02222 22220 02200 22200 22200 002",
"(2) 02000 00000 00000 00000 00000 00000 00000 00000 00000 000",
"(2) 00000 00000 00000 00000 00000 00000 00000 00000 00000 001",
"(2) 00011 00000 00000 00000 00000 00000 00000 00000 00000 000",
"(2) 00000 00000 00000 00000 00000 00000 00000 00000 00000 002",
"(2) 00000 00000 00000 00000 00000 00000 00000 00000 00000 001",
"(2) 03133 22222 00000 00000 02222 22200 00000 20000 00000 000",
"(2) 00100 11000 00000 01100 10000 00000 00011 00000 01000 001",
"(2) 02022 22100 00000 00000 02222 22200 00000 20000 00000 000",
"(2) 00100 00000 00000 00000 00000 00000 00000 00000 01000 000",
"(2) 00000 00000 00000 00000 00000 00000 00000 00000 00000 001",
"(2) 00000 00000 00000 00000 00000 00000 00000 00000 00000 001",
"(2) 00000 00000 00000 00000 00000 00000 00000 00000 01000 000",
"(2) 00000 00000 00000 00000 00000 00000 00000 00000 01000 000",
"(2) 00000 00000 00000 00000 00000 00000 00000 00000 03000 000",
"(2) 00000 00000 11100 00001 00000 00010 01100 01100 11100 001",
"(2) 00000 00000 00000 00000 00000 00000 00000 00000 00000 001",
"(2) 00000 00000 11102 00001 00000 00011 11100 01111 11010 111",
"(2) 02022 22200 00000 00000 02222 22200 00000 20000 00000 000",
"(2) 02001 00000 00000 00000 00000 00000 00000 00000 00000 000",
"(2) 00100 00010 00000 01100 10000 00000 00010 00000 01000 001",
"(2) 02033 22221 00000 00000 02222 22200 00000 20000 00000 000",
"(2) 00100 11000 00000 01100 10000 00000 00010 00000 01000 001",
"(2) 00000 00000 00000 00000 00000 00000 00000 00000 00000 001",
```

```
"(2) 03000 00000 00000 00000 00000 00000 00000 00000 00000 000",
"(2) 02022 22210 00000 00000 02222 22200 00000 20000 00000 000",
"(2) 00000 00100 00000 00000 00000 00000 00000 00000 00000 000",
"(2) 00000 00000 00000 00000 00000 00000 00000 00000 00000 001",
"(2) 00000 00000 00100 00001 00000 00010 01100 01100 10000 001",
"(2) 02033 11000 00000 00000 02111 11100 00000 20000 00000 000",
"(2) 02000 00000 00000 00000 00000 00000 00000 00000 00000 000",
"(2) 00100 11000 00000 01110 10000 00000 00010 00000 01001 001",
"(2) 00001 00000 00000 00000 00000 00000 00000 00000 00000 000",
"(2) 00011 00000 00000 00000 00000 00000 00000 00000 00000 000",
"(2) 01000 00000 00000 00000 00000 00000 00000 00000 00000 000",
"(2) 02000 00000 00000 00000 00000 00000 00000 00000 00000 000",
"(2) 02000 00000 00000 00000 00000 00000 00000 00000 00000 000",
"(2) 02000 00000 00000 00000 00000 00000 00000 00000 00000 000",
"(2) 00000 00000 00000 00000 00000 00000 00000 00000 01000 000",
"(2) 00020 00000 00000 00000 02000 00000 00000 10000 00000 000",
"(2) 00010 00000 00000 00000 00000 00000 00000 00000 00000 000",
"(2) 00000 00000 00000 00000 00000 00000 00000 00000 00000 001",
"(2) 00000 00000 00002 00000 00000 00000 00000 00000 00000 000",
"(2) 00000 00000 11100 20001 00000 00010 01100 01100 11000 001",
"(2) 02000 00000 00000 00000 00000 00000 00000 00000 00000 000",
"(2) 00100 11000 00000 01100 10000 00000 00010 00000 01000 001",
"(2) 00000 00000 00000 00000 00000 00000 00000 00000 00000 001",
"(2) 00000 00000 00000 00000 00000 00000 00000 00000 00000 002",
"(2) 00011 00000 00000 00000 00000 00000 00000 00000 00000 000",
"(2) 00000 00000 00000 10000 00000 00000 00000 00000 00000 000",
"(2) 00000 00000 11100 00001 00000 00010 01100 01100 11000 001",
"(2) 02000 00000 00000 00000 00000 00000 00000 00000 00000 000",
"(2) 02000 00000 00000 00000 00000 00000 00000 00000 00000 000",
"(2) 02000 00000 00000 00000 00000 00000 00000 00000 00000 000",
"(2) 00020 00000 00000 00000 02000 00000 00000 20000 00000 000",
"(2) 00000 00000 33300 00003 00000 00031 13300 03311 33000 103",
"(2) 00000 00000 00000 00000 00000 00000 00000 00000 00000 001",
"(2) 00000 00000 00000 00000 00000 00000 00000 00000 01000 000",
"(2) 02000 00000 00000 00000 00000 00000 00000 00000 00000 000",
"(2) 00000 00000 22200 00002 00000 00021 12200 02211 22000 102",
"(2) 00010 00000 00000 00000 01000 00000 00000 00000 00000 000",
"(2) 00020 00000 00000 00000 02000 00000 00000 20000 00000 000",
"(2) 00000 00000 22200 00002 00000 00022 22200 02222 22000 202",
"(2) 02000 00000 00000 00000 00000 00000 00000 00000 00000 000",
"(2) 00000 00000 22200 00002 00000 00022 22200 02222 22000 202");
DECLARE NC1TRIPLES LITERALLY '259';
DECLARE C1TRIPLES(NC1TRIPLES) FIXED INITIAL ( 131586, 131589, 131590, 131600,
   131601, 131604, 131617, 131618, 131625, 131631, 148995, 207108, 210729,
   262658, 262661, 262662, 262672, 262673, 262676, 262689, 262697, 262703,
   328194, 328197, 328198, 328208, 328209, 328212, 328225, 328233, 328239,
   393730, 393733, 393734, 393744, 393745, 393748, 393761, 393769, 393775,
   459266, 459269, 459270, 459280, 459281, 459284, 459297, 459305, 459311,
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    524802, 524805, 524806, 524816, 524817, 524820, 524833, 524841, 524847,
    590338, 590341, 590342, 590352, 590353, 590356, 590369, 590377, 590383,
    934145, 942090, 942091, 942092, 942099, 942108, 942111, 942112, 942116,
    942117, 942120, 942121, 942127, 1049090, 1049093, 1049094, 1049104,
    1049105, 1049108, 1049121, 1049129, 1049135, 1114626, 1114629, 1114630,
    1114640, 1114641, 1114644, 1114657, 1114665, 1114671, 1180162, 1180165,
    1180166, 1180176, 1180177, 1180180, 1180193, 1180201, 1180207, 1311234,
    1311237, 1311238, 1311248, 1311249, 1311252, 1311265, 1311273, 1311279,
    1376770, 1376773, 1376774, 1376784, 1376785, 1376788, 1376801, 1376802,
    1376809, 1376815, 2163202, 2163205, 2163206, 2163216, 2163217, 2163220,
    2163233, 2163241, 2163247, 2228738, 2228741, 2228742, 2228752, 2228753,
    2228756, 2228769, 2228770, 2228777, 2228783, 2294274, 2294277, 2294278,
    2294288, 2294289, 2294292, 2294305, 2294306, 2294313, 2294319, 3026689,
    3080961, 3146242, 3146245, 3146246, 3146256, 3146257, 3146260, 3146273,
    3146274, 3146281, 3146287, 3213097, 3358212, 3614980, 3817729, 3825674,
    3825675, 3825676, 3825683, 3825692, 3825695, 3825696, 3825700, 3825701,
    3825704, 3825705, 3825711, 3933186, 3933189, 3933190, 3933200, 3933201,
    3933204, 3933217, 3933225, 3933231, 3998210, 3998213, 3998214, 3998224,
    3998225, 3998228, 3998241, 3998249, 3998255, 3999746, 3999760, 3999761,
    3999764, 3999777, 3999785, 3999791, 4129282, 4129285, 4129286, 4129296,
    4129297, 4129300, 4129313, 4129321, 4129327, 4472323, 4472324, 4719106,
    4719109, 4719110, 4719120, 4719121, 4719124, 4719137, 4719145, 4719151,
    4736515, 4736516, 4785154, 4785157, 4785158, 4785168, 4785169, 4785172,
    4785185, 4785193, 4785199, 4850436, 5389828, 5521665, 5636610, 5636613,
    5636614, 5636624, 5636625, 5636628, 5636641, 5636649, 5636655, 5654019,
    5654020, 5713667, 5713668, 5980417, 6308097, 6372868, 6433028, 6433031);
DECLARE PRTB(122) FIXED INITIAL (0, 3824143, 5713667, 23055, 11823, 24651,
    21569, 75, 65, 11055, 11823, 32, 10, 36, 40, 47, 0, 1049158, 1114694,
    1311302, 2163270, 17470, 18502, 18476, 18521, 613, 12389, 582, 22086,
    21054, 22319, 25129, 17470, 18502, 18476, 18521, 22086, 3, 41, 62, 0,
    25129, 67, 66, 12, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 20815, 12853,
    18998, 11, 50, 0, 0, 56, 0, 0, 17925, 17926, 5, 6, 0, 823, 0, 12551, 61,
    0, 0, 24914, 13138, 19001, 97, 51, 52, 0, 56, 15624, 0, 4210185, 15364,
    18692, 17983, 9, 18, 48, 2366, 62, 0, 0, 0, 25877, 0, 96, 91, 0, 0, 0, 69,
    0, 0, 0, 20515, 34, 0, 100, 0, 0, 0, 0, 0, 0);
DECLARE PRDTB(122) BIT(8) INITIAL (0, 3, 104, 2, 103, 84, 8, 83, 7, 107, 108,
    112, 23, 117, 118, 67, 80, 40, 41, 42, 43, 111, 114, 115, 116, 51, 44, 39,
    66, 93, 106, 95, 113, 119, 120, 121, 68, 82, 25, 92, 81, 87, 94, 36, 76,
    19, 53, 54, 55, 56, 57, 58, 77, 90, 98, 110, 18, 91, 89, 20, 78, 79, 73,
    74, 61, 38, 60, 88, 65, 27, 28, 29, 30, 26, 24, 1, 33, 32, 31, 69, 86, 97,
    75, 85, 96, 109, 37, 59, 35, 34, 72, 70, 71, 52, 63, 122, 22, 64, 62, 9,
    11, 14, 46, 45, 5, 6, 4, 16, 105, 21, 10, 15, 17, 49, 48, 47, 100, 12, 99,
    50, 101, 13, 102);
DECLARE HDTB(122) BIT(8) INITIAL (0, 58, 105, 58, 103, 96, 84, 96, 84, 88,
    88, 68, 48, 72, 72, 86, 53, 66, 66, 66, 66, 85, 94, 94, 94, 95, 69, 66,
    62, 82, 87, 98, 68, 72, 72, 72, 86, 57, 55, 82, 54, 75, 98, 61, 50, 92,
    63, 63, 63, 63, 63, 63, 50, 97, 51, 52, 92, 97, 97, 76, 74, 74, 64, 78,
    56, 66, 99, 97, 62, 70, 70, 70, 70, 70, 79, 83, 49, 49, 49, 77, 75, 67,
```

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   78, 75, 67, 93, 66, 99, 59, 59, 73, 77, 60, 102, 71, 89, 81, 71, 104, 65,
   65, 92, 101, 101, 90, 90, 90, 92, 87, 76, 65, 92, 92, 80, 80, 80, 91, 65,
   91, 95, 100, 92, 100);
DECLARE PRLENGTH(122) BIT(8) INITIAL (0, 4, 4, 3, 3, 3, 3, 2, 2, 3, 3, 2, 2,
   2, 2, 2, 1, 4, 4, 4, 4, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 2,
   2, 2, 1, 3, 2, 2, 2, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 3, 3, 3, 2,
   2, 1, 1, 2, 1, 1, 3, 3, 2, 2, 1, 3, 1, 3, 2, 1, 1, 3, 3, 3, 2, 2, 2, 1, 2,
   3, 1, 4, 3, 3, 3, 2, 2, 2, 3, 2, 1, 1, 1, 3, 1, 2, 2, 1, 1, 1, 2, 1, 1, 1,
   3, 2, 1, 2, 1, 1, 1, 1, 1, 1);
DECLARE CONTEXT_CASE(122) BIT(8) INITIAL (0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
   0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
   0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
   0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
   0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
   0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0);
DECLARE LEFT_CONTEXT(0) BIT(8) INITIAL ( 0);
DECLARE LEFT_INDEX(58) BIT(8) INITIAL ( 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
   0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
   0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1);
DECLARE CONTEXT_TRIPLE(0) FIXED INITIAL ( 0);
DECLARE TRIPLE_INDEX(58) BIT(8) INITIAL ( 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
   0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
   0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1);
DECLARE PR_INDEX(105) BIT(8) INITIAL ( 1, 9, 17, 29, 41, 41, 41, 43, 44, 44,
   44, 44, 44, 45, 45, 45, 45, 45, 45, 46, 46, 46, 47, 48, 49, 50, 51, 52,
   53, 54, 55, 56, 56, 56, 56, 56, 56, 57, 58, 59, 59, 66, 67, 67, 67, 68,
   68, 69, 69, 74, 74, 74, 74, 74, 74, 75, 75, 75, 76, 79, 80, 80, 87, 87,
   87, 88, 90, 90, 90, 90, 97, 99, 99, 99, 99, 99, 100, 101, 102, 102, 104,
   104, 104, 104, 107, 108, 108, 108, 109, 109, 109, 109, 111, 112, 113, 116,
   117, 117, 117, 118, 119, 119, 120, 121, 122, 123);

/*  END OF CARDS PUNCHED BY SYNTAX                                       */

/*  DECLARATIONS FOR THE SCANNER                                         */

/* TOKEN IS THE INDEX INTO THE VOCABULARY V() OF THE LAST SYMBOL SCANNED,
   CP IS THE POINTER TO THE LAST CHARACTER SCANNED IN THE CARDIMAGE,
   BCD IS THE LAST SYMBOL SCANNED (LITERAL CHARACTER STRING). */
DECLARE (TOKEN, CP) FIXED, BCD CHARACTER;

/* SET UP SOME CONVENIENT ABBREVIATIONS FOR PRINTER CONTROL */
DECLARE EJECT_PAGE LITERALLY 'OUTPUT(1) = PAGE',
   PAGE CHARACTER INITIAL ('1'), DOUBLE CHARACTER INITIAL ('0'),
   DOUBLE_SPACE LITERALLY 'OUTPUT(1) = DOUBLE',
   X70 CHARACTER INITIAL ('
                  ');

/* LENGTH OF LONGEST SYMBOL IN V */
```

```
DECLARE (RESERVED_LIMIT, MARGIN_CHOP) FIXED;

/* CHARTYPE() IS USED TO DISTINGUISH CLASSES OF SYMBOLS IN THE SCANNER.
   TX() IS A TABLE USED FOR TRANSLATING FROM ONE CHARACTER SET TO ANOTHER.
   CONTROL() HOLDS THE VALUE OF THE COMPILER CONTROL TOGGLES SET IN $ CARDS.
   NOT_LETTER_OR_DIGIT() IS SIMILIAR TO CHARTYPE() BUT USED IN SCANNING
   IDENTIFIERS ONLY.

   ALL ARE USED BY THE SCANNER AND CONTROL() IS SET THERE.
*/
DECLARE (CHARTYPE, TX) (255) BIT(8),
        (CONTROL, NOT_LETTER_OR_DIGIT)(255) BIT(1);

/* ALPHABET CONSISTS OF THE SYMBOLS CONSIDERED ALPHABETIC IN BUILDING
   IDENTIFIERS     */
DECLARE ALPHABET CHARACTER INITIAL ('ABCDEFGHIJKLMNOPQRSTUVWXYZ_$@#');

/* BUFFER HOLDS THE LATEST CARDIMAGE,
   TEXT HOLDS THE PRESENT STATE OF THE INPUT TEXT
   (NOT INCLUDING THE PORTIONS DELETED BY THE SCANNER),
   TEXT_LIMIT IS A CONVENIENT PLACE TO STORE THE POINTER TO THE END OF TEXT,
   CARD_COUNT IS INCREMENTED BY ONE FOR EVERY SOURCE CARD READ,
   ERROR_COUNT TABULATES THE ERRORS AS THEY ARE DETECTED,
   SEVERE_ERRORS TABULATES THOSE ERRORS OF FATAL SIGNIFICANCE. */
DECLARE (BUFFER, TEXT) CHARACTER,
   (TEXT_LIMIT, CARD_COUNT, ERROR_COUNT, SEVERE_ERRORS, PREVIOUS_ERROR) FIXED
   ;

/* NUMBER_VALUE CONTAINS THE NUMERIC VALUE OF THE LAST CONSTANT SCANNED,
*/
DECLARE NUMBER_VALUE FIXED;

/* EACH OF THE FOLLOWING CONTAINS THE INDEX INTO V() OF THE CORRESPONDING
   SYMBOL.   WE ASK:    IF TOKEN = IDENT    ETC.    */
DECLARE (IDENT, NUMBER, DIVIDE, EOFILE) FIXED;

/* STOPIT() IS A TABLE OF SYMBOLS WHICH ARE ALLOWED TO TERMINATE THE ERROR
   FLUSH PROCESS.  IN GENERAL THEY ARE SYMBOLS OF SUFFICIENT SYNTACTIC
   HIERARCHY THAT WE EXPECT TO AVOID ATTEMPTING TO START CHECKING AGAIN
   RIGHT INTO ANOTHER ERROR PRODUCING SITUATION.  THE TOKEN STACK IS ALSO
   FLUSHED DOWN TO SOMETHING ACCEPTABLE TO A STOPIT() SYMBOL.
   FAILSOFT IS A BIT WHICH ALLOWS THE COMPILER ONE ATTEMPT AT A GENTLE
   RECOVERY.   THEN IT TAKES A STRONG HAND.   WHEN THERE IS REAL TROUBLE
   COMPILING IS SET TO FALSE, THEREBY TERMINATING THE COMPILATION.
*/
DECLARE STOPIT(100) BIT(1), (FAILSOFT, COMPILING) BIT(1);

DECLARE S CHARACTER;  /* A TEMPORARY USED VARIOUS PLACES */
```

```
/* THE ENTRIES IN PRMASK() ARE USED TO SELECT OUT PORTIONS OF CODED
   PRODUCTIONS AND THE STACK TOP FOR COMPARISON IN THE ANALYSIS ALGORITHM */
DECLARE PRMASK(5) FIXED INITIAL (0, 0, "FF", "FFFF", "FFFFFF", "FFFFFFFF");


/*THE PROPER SUBSTRING OF POINTER IS USED TO PLACE AN  |  UNDER THE POINT
   OF DETECTION OF AN ERROR DURING CHECKING.  IT MARKS THE LAST CHARACTER
   SCANNED.  */
DECLARE POINTER CHARACTER INITIAL ('
                                                |');
DECLARE CALLCOUNT(20) FIXED   /* COUNT THE CALLS OF IMPORTANT PROCEDURES */
   INITIAL(0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0);

/* RECORD THE TIMES OF IMPORTANT POINTS DURING CHECKING */
DECLARE CLOCK(5) FIXED;


/* COMMONLY USED STRINGS */
DECLARE X1 CHARACTER INITIAL(' '), X4 CHARACTER INITIAL('    ');
DECLARE PERIOD CHARACTER INITIAL ('.');

/* TEMPORARIES USED THROUGHOUT THE COMPILER */
DECLARE (I, J, K, L) FIXED;

DECLARE TRUE LITERALLY '1', FALSE LITERALLY '0', FOREVER LITERALLY 'WHILE 1';

/*  THE STACKS DECLARED BELOW ARE USED TO DRIVE THE SYNTACTIC
   ANALYSIS ALGORITHM AND STORE INFORMATION RELEVANT TO THE INTERPRETATION
   OF THE TEXT.  THE STACKS ARE ALL POINTED TO BY THE STACK POINTER SP.  */

DECLARE STACKSIZE LITERALLY '75';  /* SIZE OF STACK  */
DECLARE PARSE_STACK (STACKSIZE) BIT(8); /* TOKENS OF THE PARTIALLY PARSED
                                           TEXT */
DECLARE VAR (STACKSIZE) CHARACTER;/* EBCDIC NAME OF ITEM */
DECLARE FIXV (STACKSIZE) FIXED;   /* FIXED (NUMERIC) VALUE */

/* SP POINTS TO THE RIGHT END OF THE REDUCIBLE STRING IN THE PARSE STACK,
   MP POINTS TO THE LEFT END, AND
   MPP1 = MP+1.
*/
DECLARE (SP, MP, MPP1) FIXED;


DECLARE
     ADVANCE LITERALLY 'CALL ADVANCE_PAGE',
     AFLAGCK LITERALLY 'CALL AFLAG_CHECK',
     EMIT LITERALLY 'CALL STORE_CODE',
```

```
        EMITA LITERALLY 'CALL EMIT_ADDRESS',
        EMITCAR LITERALLY 'CALL STORE_ASCII_CODE',
        EMITCK LITERALLY 'CALL EMIT_CHECK',
        CONSIZE LITERALLY '1023';  7* SIZE OF CONSTANT ARRAYS */

DECLARE
   AFLAG BIT(8) INITIAL(0),    /* INDICATES PROCESSING REAL EXPRESSIONS        */
   AT BIT(8) INITIAL(0),       /* POINTER TO TOP OF VCELL_ADDRESS TABLE        */
   BEGIN BIT(8) INITIAL(0),    /* SETS UP JUMP TO MAIN IF SUBPROGRAMS PRECEED */
   BUFFER1 CHARACTER,          /* CONTAINS NEXT CARD IMAGE TO BE SCANNED       */
   BUFFER2 CHARACTER INITIAL(' '), /* TEMPORARILY HOLDS FORTRAN STATEMENT     */
   CA BIT(16) INITIAL(2845),   /* POINTS TO NEXT VARIABLE ARRAY SPACE          */
   CB BIT(16) INITIAL(128),    /* NEXT INSTRUCTION CELL TO BE ALLOCATED        */
   CFLAG BIT(8) INITIAL(0),    /* INDICATES CALL TO SUBROUTINE                 */
   CODE(4095) FIXED,           /* CONTAINS CODE FOR PDP-8                      */
   CONSTANT1(CONSIZE) FIXED,   /* LOWER 12 BITS=EXPONENT,NEXT 12 OCTAL LOCATION */
   CONSTANT2(CONSIZE) FIXED,   /* MANTISSA OR NUMBER < 409                     */
   CT BIT(16) INITIAL(255),    /* TOP LOCATION OF PRESENT PAGE                 */
   DFLAG BIT(8) INITIAL(3),     /* DETERMINES ACTION FOR DECLARATIONS          */
   DIM(70) FIXED,              /* TEMPORARY ARRAY FOR SUBSCRIPTING             */
   DT FIXED,                   /* POINTER WITHIN DIM ARRAY                     */
   EP FIXED INITIAL(128),      /* USED FOR CODE OUTPUT WHILE COMPILING         */
   ENTRY FIXED,                /* CONTAINS PROCEDURE ENTRY & FUNCTION RETURN   */
   FIXM(STACKSIZE) FIXED,      /* HOLDS MANTISSA OF REAL NUMBER                */
   (HOLD1,HOLD2) FIXED,        /* PASSES REAL NUMBERS TO COMPILATION_LOOP      */
   LAB(253) FIXED,             /* CONTAINS LABEL ENTRIES                       */
   LOC(STACKSIZE) FIXED,       /*CODE LOCATIONS OF VARIABLE OR CONSTANT        */
   MAXTCELL BIT(16) INITIAL(62), /* MAX NO. TEMP CELLS IN USE DURING COMPILE */
   NEXT BIT(8) INITIAL(0),     /* NEXT PARAMETER TO BE ASSIGNED THIS ADDRESS   */
   NFLAG BIT(8) INITIAL(0),    /* INDICATES NEXT NUMBER IN SCAN IS A REAL      */
   PAGE_BASE BIT(16) INITIAL(128), /* LOCATION ZERO OF PRESENT PAGE           */
   PAGE_BLOCK BIT(16) INITIAL(128), /* UPDATES LABELS WITHIN THIS BLOCK       */
   PARM BIT(8),                /* IF 1 THEN VARIABLE IS A PARAMETER            */
   PARMCELL BIT(8) INITIAL(127), /* POINTER TO PASS PARAMETER                 */
   PC FIXED INITIAL(1),        /*POINTER INTO PTABLE & PSYMBOL                 */
   PCELL BIT(8) INITIAL(16),   /* NEXT CELL FOR PROCEDURE INDIRECT ADDRESSING */
   PRT(383) FIXED,             /* HOLDS ADDRESS,TYPE,ETC. OF IDENTIFIER        */
   PSYMBOL(13) CHARACTER,      /* HOLDS NAMES OF PROCEDURES                    */
   PT FIXED INITIAL(147),      /* ADDRESSES TOP OF PRT                         */
   PTABLE(13) FIXED,           /* HOLDS STATISTICS ON PROCEDURES               */
   RFLAG BIT(8) INITIAL(0),    /* CHECKS FOR RETURN STATEMENT IN SUBPROGRAMS   */
   (SAVE_LABEL_ADDRESS,SAVE_FIRST,STEP,DO_UNTIL) FIXED, /* DO STATE. VARIABLE */
   SC BIT(8) INITIAL(0),       /* NEXT COMMON CELL IN SYMBOL TABLE             */
   SFLAG BIT(8) INITIAL(0),    /* INDICATES SCANNING A SUBPROGRAM              */
   SIZE(255) BIT(16),          /* CONTAINS NUMBER OF CELLS ASSOC. WITH VARIABLE */
   ST FIXED INITIAL(19),       /* ADDRESSES TOP OF SYMBOL TABLE                */
   STOP BIT(8) INITIAL(1),     /* CHECKS FOR STOP STATEMENT IN MAIN PROGRAM    */
```

```
   STRING FIXED,               /* TOKEN INDEX FOR V SET IN INITIALIZE          */
   SYMBOL(255) CHARACTER,      /* HOLDS VARIABLE NAMES                         */
   TCELL BIT(16) INITIAL(62), /* POINTS TO NEXT TEMPORARY CELL                 */
   TYPE FIXED,                 /* VARIABLE TYPE, SET IN LOOKUP & ENTER         */
   VCELL_ADDRESS(127) FIXED; /* ADDRESSES OF VARIABLES ON OTHER PAGES          */

   /* FLOAT SUBPROGRAM CONVERTS AN INTEGER TO REAL */
DECLARE FLOAT(30) BIT(16) INITIAL(0,3648,3904,2723,3664,242,1574,3776,
      1572,3716,4008,2731,754,3616,3857,550,3880,2738,1060,3592,2733,
      550,3912,2743,3588,2739,3592,3905,1573,1574,2973);

   /* WRITE_STRING ARRAY CONTAINS TWO SUBPROGRAMS
         SUBPROGRAM              NUMBER OF INSTRUCTIONS        OCTAL LOCATIONS
      TAB                                  15                       5474-5513
      WRITE_STRING                         12                       5514-5527 */
DECLARE WRITE_STRING(27) BIT(16) INITIAL(0,956,1739,1212,2333,141,0,715,
      4032,3004,2333,160,0,1227,2755,0,0,3776,3110,972,1228,3880,3020,
      3105,2771,3110,3776,2767);

   /* INTEGER_IO ARRAY CONTAINS TWO SUBPROGRAMS
         SUBPROGRAM              NUMBER OF INSTRUCTIONS        OCTAL LOCATIONS
      INTEGER OUTPUT                       27                       5530-5562
      INTEGER INPUT                        13                       5563-5577 */
DECLARE INTEGER_IO(39) BIT(16) INITIAL(0,1573,549,4032,2786,549,3616,
      516,1573,754,3857,1574,1572,549,3592,1060,3872,2790,549,3588,3904,
      2795,3592,3905,1573,3032,2048,0,548,767,4032,2813,549,3656,1573,
      1060,2804,549,3059,4085);

   /* SUBPROGS ARRAY CONTAINS FOUR SUBPROGRAMS WHICH ARE PRELOADED
      ALONG WITH FLOATING POINT PACKAGE(DIGITAL 8-5A-S). PROGRAM
      EXECUTION WILL OVERLAY RIM LOADER LOCATION 7756-7775 OCTAL
         SUBPROGRAM              NUMBER OF INSTRUCTIONS        OCTAL LOCATIONS
       ARRAY SUBSCRIPTOR                   42                       7600-7651
       MULTIPLY                            18                       7652-7673
       DIVIDE                              28                       7674-7727
       EXPONENTIATE                        22                       7730-7755 */
DECLARE SUBPROGS(109) BIT(16) INITIAL(0,896,1775,1152,1007,1776,1263,
      563,3904,2703,3616,1774,750,750,750,1774,1264,2707,2721,1264,1007,
      1777,1263,563,3616,516,1778,754,1266,2715,750,1774,2704,647,1687,
      1007,3616,515,751,750,2688,   0,0,3776,938,1774,1006,1774,1194,938,
      1775,1007,3616,1775,1194,1263,2746,2986,750,2743,0,3776,956,1774,
      1006,1774,1212,956,1212,1775,1007,3616,516,3872,2764,3842,1775,
      1776,750,751,1264,3936,2767,3904,2774,514,752,3004,0,3776,984,
      1774,1006,3616,516,1774,1240,984,1775,1240,2311,3055,3311,0,2311,
      1775,0,1262,2792,3032);

   /* ARRAYS A OF 56 THROUGH 74 CONTAIN FLOATING POINT PACKAGE */
```

```
DECLARE
    A56(127) BIT(16) INITIAL(0,3776,1571,1575,896,1707,683,179,4008,
     2700,689,128,1710,690,171,686,1710,692,171,4008,2711,942,
     1710,1152,942,1568,686,1711,1199,943,1569,1199,943,1570,683,3654,
     3590,176,693,1708,940,1708,2988,0,0,0,0,0,15,3968,127,128,256,
     2998,3042,3022,3039,3057,3269,3006,3013,3067,544,1572,545,1573,
     546,1574,2689,548,1966,1198,549,1966,1198,550,1966,2689,2553,
     2689,2554,3648,547,551,1575,3588,546,550,1574,3588,545,549,1573,
     2552,2689,2529,2766,3328,683,176,3680,2944,752,1708,940,1708,
     0640,1709,2476,685,1664,2689,3428,3713,544,548,1572,2551,2689,
     3217,3456,3088,3444,2552,2689,0,0,0),
    A60(127) BIT(16) INITIAL(0,3776,551,3617,1575,550,3616,3864,3649,
     1574,549,3616,3864,3649,1573,2944,0,549,4000,2711,550,4008,2783,
     545,4000,2717,546,4008,2960,544,3617,548,3880,2764,3904,3617,1762,
     738,739,4032,2734,2254,3864,744,743,2773,2254,3856,744,743,1764,
     738,3617,996,2020,1252,740,1765,1253,741,1766,1254,3648,996,
     3912,3600,3592,2020,997,3592,2021,998,3592,2022,1250,2750,1168,
     2960,0,544,3617,548,3588,3712,3022,1764,996,1572,1252,996,1573,
     1252,996,1574,2960,544,1572,2764,0,24,0,0,0,36,4092,2945,754,
     1572,754,1573,3616,1574,1073,3049,2047,0,2311,3114,1578,0,3059,
     0,3065,0,0,0,0,0),
    A62(127) BIT(16) INITIAL(0,3776,549,3912,3664,3592,1573,550,3592,
     1574,551,3592,1575,3648,1060,3584,2944,0,3776,755,1767,2270,546,
     2030,550,2541,3712,1007,1575,549,2030,546,2541,551,1575,3588,
     1007,1783,3588,1784,545,2030,550,2541,551,1575,3588,1007,759,
     1783,3588,760,1784,549,2030,545,2541,759,1574,3588,1007,760,1573,
     2544,1575,1269,2961,2555,2961,545,4000,2763,546,4008,3068,544,
     3617,548,3585,1572,754,1767,2270,2545,1007,545,3992,3585,1570,
     1569,1269,2555,3037,3024,0,758,1781,549,4032,2790,2555,1269,
     545,4032,3038,2553,1269,3584,3038,3359,3385,3381,3456,3386,4040,
     4032,2945,0,4094,0,0,3328,3344,3072,3178,0,0,0),
    A64(127) BIT(16) INITIAL(0,3776,547,3617,1571,546,3616,3864,3649,
     1570,545,3616,3864,3649,1569,2944,0,3776,545,3912,3664,3592,1569,
     546,3592,1570,547,3592,1571,3648,2960,0,1718,1717,696,1719,3648,
     694,3592,1718,693,3856,2733,3648,697,3592,1717,1207,2725,694,3592,
     3648,2975,0,0,0,4084,0,0,3776,1577,740,1719,2758,550,3588,1574,
     549,3588,1573,546,550,1721,3588,549,545,3856,2769,1573,697,1574,
     3712,553,3588,1577,551,3588,1575,1207,2752,553,1574,549,3654,1717,
     551,1573,1575,693,3002,4073,3187,3502,3193,3193,3193,3193,3193,
     3193,3193,3193,3193,3193,3193,3193,3193,0,2192,2554,1056,3584,
     3060,3200,0,0,0,0,0),
    A66(127) BIT(16) INITIAL(0,3776,1709,1708,549,3912,1196,4000,
     2703,550,4000,2703,551,4008,2729,684,4000,2475,549,3652,4040,
     2721,551,3652,1575,550,3588,1574,549,3588,1573,1197,2706,685,
     3617,548,1572,684,4000,2475,2944,1572,2944,3072,0,0,0,1778,2311,
     3114,0,549,4040,2793,548,3648,3912,3600,3592,1774,3864,1262,3584,
     753,1775,1776,555,4000,2760,556,4008,2796,2311,2602,2286,750,0,
     3744,548,1572,548,3617,750,4000,2789,549,3617,751,4000,2789,550,
```

```
      3617,752,3904,3617,3585,4040,2789,754,1585,2990,2311,3310,0,2760,
      2475,1266,2736,1572,2990,0,0,0,1549,0,0,0,0,0,558,4008,3063,
      767,2558,3063,3812,138),
     A70(127) BIT(16) INITIAL(0,3712,1573,1574,1717,1718,2274,734,3880,
      2703,733,3872,2704,3744,1717,2274,3712,559,735,3904,2944,736,
      3912,2944,1715,549,225,3872,2703,1072,1206,2209,2703,0,550,1713,
      549,1714,1716,2231,2231,2243,2231,691,1713,1714,2243,692,2977,
      0,0,0,0,0,0,0,3776,550,3588,1574,549,3588,1573,692,3588,1716,2999,
      0,3776,550,689,1574,3588,549,690,1573,3588,692,1716,3011,0,3776,
      1205,3024,550,3617,1574,549,3616,3864,3585,1573,3024,4094,3925,3910,
      10,3968,0,3712,3097,2788,3102,1583,559,2550,559,3880,2787,760,
      3880,3063,761,4008,2549,559,3042,3575,3812,3841,3841,114,0,0,0,0,0,0),
     A72(127) BIT(16) INITIAL(0,2191,724,1572,739,2276,2527,557,4008,
      2944,737,2276,738,2276,2944,0,3776,549,4040,3728,727,3864,728,
      2276,2282,729,2276,3776,549,4032,2722,3616,2011,2522,3744,548,1572,
      1748,548,3904,2739,726,4032,2744,2311,2016,0,3744,724,1748,2726,
      2311,1786,0,1236,2726,2012,2526,2525,3848,2287,1060,2748,3880,
      2761,2282,725,1572,2525,2282,1060,2756,2959,3744,724,1748,549,
      4000,2770,550,4008,1748,3744,2754,0,4090,4,171,2,174,3664,3637,3635,
      3617,3639,3922,3908,141,138,197,0,3105,2789,3110,3712,3044,0,
      750,2276,3050,176,0,3656,1764,549,3592,1573,550,3592,1574,740,
      3055,4093,1638,1639,0,0,0),
     A74(127) BIT(16) INITIAL(0,3744,1739,1584,2510,3712,559,714,4000,
      2704,715,4008,2706,2001,1739,3023,715,4008,977,3617,1740,2512,
      713,1572,2311,3584,3114,0,559,712,4000,2730,2510,2512,549,3912,
      3585,4000,2751,550,716,1740,2311,2602,0,716,3880,2944,4032,2744,2311,
      1991,0,1228,2733,2944,2311,1732,0,3744,716,1740,2733,717,1572,
      717,1573,2944,4,1280,0,3834,3899,23,3922,0,0,2047,3584,3599,
      3664,3638,0,3776,548,3912,3633,1572,758,3864,759,2556,1573,548,1061,
      760,3904,2782,761,1572,3616,549,3872,2556,1573,548,1061,762,3904,
      2794,763,1574,3744,549,2556,550,2556,3026,4091,2,3996,100,4086,
      10,3818,0,0,0);


   /*                 P R O C E D U R E S                              */


I_FORMAT:
   PROCEDURE (NUMBER, WIDTH) CHARACTER;
      DECLARE (NUMBER, WIDTH, L) FIXED, STRING CHARACTER;
      STRING = NUMBER;
      L = LENGTH(STRING);
      IF L >= WIDTH THEN RETURN STRING;
      ELSE RETURN SUBSTR(X70, 0, WIDTH-L) || STRING;
   END I_FORMAT;
```

```
READ_OCTAL:
   PROCEDURE(N) FIXED;
         /* OCTAL BINARY N CHANGED TO OCTAL NUMBER REPRESENTATION */
      DECLARE (M,N) FIXED;
      M=(SHR(N,9) & "7") * 1000;  M=M+((SHR(N,6) & "7") * 100);
      M=M+((SHR(N,3) & "7") * 10);  M=M+(N & "7");  RETURN M;
   END READ_OCTAL;

LIST_CARD:
   PROCEDURE(S);
         /*  PRINTS THE FORTRAN STATEMENT  */
      DECLARE (C,S,REST) CHARACTER, I FIXED;
      IF BUFFER2=' ' THEN DO; BUFFER2=S;
                              RETURN;   END;
      C=BUFFER2;  BUFFER2=S;
      CARD_COUNT=CARD_COUNT+1;
      IF MARGIN_CHOP > 0 THEN
        DO;  /* THE MARGIN CONTROL FROM DOLLAR | */
           I=LENGTH(C) - MARGIN_CHOP;  REST=SUBSTR(C,I);
           C=SUBSTR(C,0,I);  END;
        ELSE REST=' ';
      IF CONTROL(BYTE('M')) THEN OUTPUT=C;
         ELSE IF CONTROL(BYTE('L')) THEN
            OUTPUT=I_FORMAT(CARD_COUNT,4) || '|' || C || '|' || REST;
      IF CONTROL(BYTE('C')) THEN DO I=EP TO CB-1;
         EP=CODE(I);  C='              '||READ_OCTAL(I)||'     ';
         IF EP<4096 THEN OUTPUT=C||READ_OCTAL(EP);
          ELSE IF EP=4096 THEN OUTPUT=C||'----FEXT';
          ELSE IF EP=4097 THEN OUTPUT=C||'----WEXT';
          ELSE OUTPUT=C||'----LABEL= '||LAB(SHR(EP,16));  END;
      CP=0;  EP=CB;
   END LIST_CARD;

ERROR:
   PROCEDURE(MSG, SEVERITY);
      /* PRINTS AND ACCOUNTS FOR ALL ERROR MESSAGES */
      /* IF SEVERITY IS NOT SUPPLIED, 0 IS ASSUMED */
      DECLARE MSG CHARACTER, SEVERITY FIXED;
      CALL LIST_CARD(' '); /* FORCE THE LISTING OF THE CARD IN BUFFER2 */
      ERROR_COUNT = ERROR_COUNT + 1;
      /* IF LISTING IS SUPPRESSED, FORCE PRINTING OF THIS LINE */
      IF ¬ CONTROL(BYTE('L')) THEN
         OUTPUT = I_FORMAT (CARD_COUNT, 4) || ' |' || BUFFER || '|';
      OUTPUT = SUBSTR(POINTER, TEXT_LIMIT-CP+MARGIN_CHOP);
      OUTPUT = '*** ERROR, ' || MSG ||
            '.  LAST PREVIOUS ERROR WAS DETECTED ON LINE ' ||
            PREVIOUS_ERROR || '.  ***';
```

```
      PREVIOUS_ERROR = CARD_COUNT;
      IF SEVERITY > 0 THEN
         IF SEVERE_ERRORS > 25 THEN
            DO;
               OUTPUT = '*** TOO MANY SEVERE ERRORS, CHECKING ABORTED ***';
               COMPILING = FALSE;  END;
         ELSE SEVERE_ERRORS = SEVERE_ERRORS + 1;
   END ERROR;



 /*                      CARD IMAGE HANDLING PROCEDURE                      */


GET_CARD:
   PROCEDURE;
      DECLARE (FLAG,I) FIXED, C CHARACTER;
        /* FLAG HOLDS COUNT OF CONTINUATION CARDS - - I DETERMINES
           WHERE TO INSERT ; FOR END OF STATEMENT  */
      I=72;   FLAG=0;   BUFFER=BUFFER1;
      DO FOREVER;
        C=SUBSTR(BUFFER,0,1);
        IF C=' ' THEN
           DO FOREVER;
               BUFFER1=INPUT;
               IF (SUBSTR(BUFFER1,0,1)='C') | (SUBSTR(BUFFER1,5,1)=' ')
                  THEN DO; IF FLAG=0 THEN CALL LIST_CARD(BUFFER);
                              BUFFER=SUBSTR(BUFFER,0,I) || ';'  ;
                              TEXT=BUFFER;   TEXT_LIMIT=LENGTH(TEXT) -1;
                              RETURN;
                           END;   /* ELSE A CONTINUATION  */
               IF FLAG=0 THEN CALL LIST_CARD(BUFFER);
                         ELSE IF FLAG > 2 THEN
                              DO;CALL ERROR('ONLY 2 CONTINUATIONS ALLOWED',2);
                                    RETURN;  END;
               CALL LIST_CARD(BUFFER1);
               BUFFER=SUBSTR(BUFFER,0,I) || SUBSTR(BUFFER1,6,66);
               FLAG=FLAG+1;   I=I+66;   END;
        IF C='C' THEN CALL LIST_CARD(BUFFER);
          ELSE IF SUBSTR(BUFFER,0,3)='$GO' THEN
               DO; CALL LIST_CARD(BUFFER);  TEXT='EOF;  ';
                  TEXT_LIMIT=LENGTH(TEXT)-1;  BUFFER1='$EOF;  ';  RETURN;
             END;
          ELSE IF SUBSTR(BUFFER,0,4)='$EOF' THEN
               DO; TEXT='EOF;  ';  TEXT_LIMIT=LENGTH(TEXT)-1;  RETURN;  END;
          ELSE DO; I=BYTE(BUFFER,1);  CONTROL(I)= ¬CONTROL(I);
```

```
                CALL LIST_CARD(BUFFER);  I=72;  END;
         BUFFER,BUFFER1=INPUT;  END;
   END GET_CARD;

   /*                THE SCANNER PROCEDURES                */


COMPUTE:
   PROCEDURE (M,N,P);
        /* CONVERTS DECIMAL FRACTIONS TO OCTAL EXPONENTIAL (REAL)
           RETURNS EXPONENT IN HOLD1 AND MANTISSA IN HOLD2 */
      DECLARE (I,J,K,L,M,N,P) FIXED, C CHARACTER;
      J=0;
      DO I=1 TO 8;
        C=N * 8;
        IF LENGTH(C)>M THEN DO; K=BYTE(C) - "F0";  J=SHL(J,3) | K;
                              DO L=2 TO LENGTH(C);  K=K*10;  END;
                              N=N * 8 - K;  END;
                      ELSE DO; N=N * 8;  J=SHL(J,3);  END;  END;
      N=SHL(J,8);  J=1;
      DO I=0 TO 30;
        IF P<J THEN GO TO FINISH;  J=SHL(J,1);  END;
      FINISH: HOLD1=I;  HOLD2=SHR( (SHR(N,I) | SHL(P,32-I) ),9);
      IF NUMBER_VALUE > 0 THEN RETURN;
      /* HAVE TO RESET FOR NUMBER < 0.5 */
      IF SHR(HOLD2,22)=1 THEN RETURN;
      HOLD1=4095;  HOLD2=SHL(HOLD2,1);
      DO I=1 TO 24;
         IF SHR(HOLD2,22)=1 THEN RETURN;
         HOLD1=HOLD1-1;  HOLD2=SHL(HOLD2,1);  END;
      CALL ERROR('UNABLE TO CONVERT NUMBER',2);
         OUTPUT='NUMBER= '||NUMBER_VALUE||'.'||SUBSTR(TEXT,CP-M,M);
   END COMPUTE;


SCAN:
   PROCEDURE;
      DECLARE(S1,S2,S3) FIXED;
      CALLCOUNT(3) = CALLCOUNT(3) + 1;
      FAILSOFT = TRUE;
      BCD = '';  NUMBER_VALUE = 0;
   SCAN1:
      DO FOREVER;
         IF CP > TEXT_LIMIT THEN CALL GET_CARD;
         ELSE
            DO; /* DISCARD LAST SCANNED VALUE */
               TEXT_LIMIT = TEXT_LIMIT - CP;
               TEXT = SUBSTR(TEXT, CP);
```

```
         CP = 0;  END;
   /*  BRANCH ON NEXT CHARACTER IN TEXT                          */
   DO CASE CHARTYPE(BYTE(TEXT));

      /*  CASE 0  */
      /* ILLEGAL CHARACTERS FALL HERE  */
      CALL ERROR ('ILLEGAL CHARACTER: ' || SUBSTR(TEXT, 0, 1));

      /*  CASE 1  */
      /*  BLANK  */
      DO;
         CP = 1;
         DO WHILE BYTE(TEXT, CP) = BYTE(' ') & CP <= TEXT_LIMIT;
            CP = CP + 1;  END;
         CP = CP - 1;  END;

      /*  CASE 2  */
;     /*  NOT USED IN SKELETON (BUT USED IN XCOM)  */

      /*  CASE 3  */
      DO; /* LOCATE STRING AND PLACE IN BCD */
          TOKEN=STRING;
          DO CP=CP+1 TO TEXT_LIMIT;
             S1=BYTE(TEXT,CP);
             IF S1=125 THEN DO;  CP=CP+1;  RETURN;  END;
             BCD=BCD || SUBSTR(TEXT,CP,1);  END;  END;

      /*  CASE 4  */
      DO FOREVER;  /* A LETTER:  IDENTIFIERS AND RESERVED WORDS */
         DO CP = CP + 1 TO TEXT_LIMIT;
            IF NOT_LETTER_OR_DIGIT(BYTE(TEXT, CP)) THEN
               DO;  /* END OF IDENTIFIER  */
                  IF CP > 0 THEN BCD = BCD || SUBSTR(TEXT, 0, CP);
    RES_WORD:     S1=LENGTH(BCD);
                  IF S1 > 1 THEN IF S1 <= RESERVED_LIMIT THEN
                     /* CHECK FOR RESERVED WORDS */
                     DO I = V_INDEX(S1-1) TO V_INDEX(S1) - 1;
                        IF BCD = V(I) THEN
                           DO;
                              TOKEN = I;
                              RETURN;  END;  END;
                  /*  RESERVED WORDS EXIT HIGHER: THEREFORE <IDENTIFIER>*/
                  TOKEN = IDENT;
                  RETURN;  END;  END;
         /*  END OF CARD  */
         BCD = BCD || TEXT;
         CALL GET_CARD;
         CP = -1;  END;
```

```
         /*  CASE 5  */
         DO;       /*  DIGIT:  A NUMBER  */
           TOKEN=NUMBER;  NFLAG=0;
           DO FOREVER;
             DO CP=CP TO TEXT_LIMIT;
               S1=BYTE(TEXT,CP);
               IF S1=BYTE('.') THEN
                DO; CP=CP+1;  S2,S3=0;  NFLAG=1;
                  DO FOREVER;
                    DO CP=CP TO TEXT_LIMIT;
                      S1=BYTE(TEXT,CP);
                      IF S1 < "F0" THEN
                        DO; IF NUMBER_VALUE + S3 = 0
                                THEN HOLD1,HOLD2=0; /* VALUE IS 0.0 */
                                ELSE CALL COMPUTE(S2,S3,NUMBER_VALUE);
                            RETURN;  END;
                      S2=S2+1;  S3=10 * S3 + S1 - "F0";  END;
                      CALL GET_CARD;  END;  END;
               IF S1 < "F0" THEN RETURN;
               NUMBER_VALUE=10*NUMBER_VALUE + S1 - "F0";  END;
             CALL GET_CARD;  END;  END;

         /*  CASE 6  */
      ;  /*  CASE 6 NOT UTILIZED  */

         /*  CASE 7  */
         DO;       /*  SPECIAL CHARACTERS  */
            TOKEN = TX(BYTE(TEXT));
            CP = 1;
            RETURN;  END;

         /*  CASE 8  */
      ;  /*  NOT USED IN SKELETON (BUT USED IN XCOM)  */

         /*   CASE 9   */
         /*  DETERMINATION OF PERIOD  */
         DO; BCD='.';  CP=CP+1;
            DO FOREVER;
              IF BYTE(TEXT,CP) = BYTE('.') THEN
                    DO;  BCD= BCD || '.';  CP=CP+1;
                         GO TO RES_WORD;  END;
              ELSE IF BYTE(TEXT,CP) ¬= BYTE(' ') THEN
                       BCD=BCD ||SUBSTR(TEXT,CP,1);
              CP=CP+1;  END;  END;
      END;    /* OF CASE ON CHARTYPE  */
      CP = CP + 1;  /* ADVANCE SCANNER AND RESUME SEARCH FOR TOKEN  */
   END;
```

```
   END SCAN;


  /*                          TIME AND DATE                          */


PRINT_TIME:
   PROCEDURE (MESSAGE, T);
      DECLARE MESSAGE CHARACTER, T FIXED;
      MESSAGE = MESSAGE || T/360000 || ':' || T MOD 360000 / 6000 || ':'
         || T MOD 6000 / 100 || '.';
      T = T MOD 100;  /* DECIMAL FRACTION  */
      IF T < 10 THEN MESSAGE = MESSAGE || '0';
      OUTPUT = MESSAGE || T || '.';
   END PRINT_TIME;

PRINT_DATE_AND_TIME:
   PROCEDURE (MESSAGE, D, T);
      DECLARE MESSAGE CHARACTER, (D, T, YEAR, DAY, M) FIXED;
      DECLARE MONTH(11) CHARACTER INITIAL ('JANUARY', 'FEBRUARY', 'MARCH',
         'APRIL', 'MAY', 'JUNE', 'JULY', 'AUGUST', 'SEPTEMBER', 'OCTOBER',
         'NOVEMBER', 'DECEMBER'),
      DAYS(12) FIXED INITIAL (0, 31, 60, 91, 121, 152, 182, 213, 244, 274,
         305, 335, 366);
      YEAR = D/1000 + 1900;
      DAY = D MOD 1000;
      IF (YEAR & "3") ¬= 0 THEN IF DAY > 59 THEN DAY = DAY + 1; /* ¬ LEAP YEAR*/
      M = 1;
      DO WHILE DAY > DAYS(M);  M = M + 1;  END;
      CALL PRINT_TIME(MESSAGE || MONTH(M-1) || X1 || DAY-DAYS(M-1) ||  ', '
         || YEAR || '.  CLOCK TIME = ', T);
   END PRINT_DATE_AND_TIME;

  /*                          INITIALIZATION                          */


INITIALIZATION:
   PROCEDURE;
      EJECT_PAGE;
   CALL PRINT_DATE_AND_TIME ('   SYNTAX CHECK -- STANFORD UNIVERSITY -- SKELETON
 III VERSION OF ', DATE_OF_GENERATION, TIME_OF_GENERATION);
      DOUBLE_SPACE;
      CALL PRINT_DATE_AND_TIME ('TODAY IS ', DATE, TIME);
      DOUBLE_SPACE;
      DO I = 1 TO NT;
```

```
      S = V(I);
      IF S = '<NUMBER>' THEN NUMBER = I;  ELSE
      IF S= '<STRING>' THEN STRING=I;  ELSE
      IF S = '<IDENTIFIER>' THEN IDENT = I;  ELSE
      IF S = '/' THEN DIVIDE = I;  ELSE
      IF S = '_|_' THEN EOFILE = I;  ELSE
      IF S = ';' THEN STOPIT(I) = TRUE;  ELSE
      ;
   END;
   IF IDENT = NT THEN RESERVED_LIMIT = LENGTH(V(NT-1));
   ELSE RESERVED_LIMIT = LENGTH(V(NT));
   V(EOFILE) = 'EOF';
   STOPIT(EOFILE) = TRUE;
   CHARTYPE(BYTE(' ')) = 1;
   DO I = 0 TO 255;
      NOT_LETTER_OR_DIGIT(I) = TRUE;
   END;
   DO I = 0 TO LENGTH(ALPHABET) - 1;
      J = BYTE(ALPHABET, I);
      TX(J) = I;
      NOT_LETTER_OR_DIGIT(J) = FALSE;
      CHARTYPE(J) = 4;
   END;
   DO I = 0 TO 9;
      J = BYTE('0123456789', I);
      NOT_LETTER_OR_DIGIT(J) = FALSE;
      CHARTYPE(J) = 5;
   END;
   DO I = V_INDEX(0) TO V_INDEX(1) - 1;
      J = BYTE(V(I));
      TX(J) = I;
      CHARTYPE(J) = 7;
   END;
   CHARTYPE(BYTE('/')) = 6;
   /* FIRST SET UP GLOBAL VARIABLES CONTROLLING SCAN, THEN CALL IT */
   CP = 0;  TEXT_LIMIT = -1;
   TEXT = '';
   CONTROL(BYTE('C'))=FALSE; /* OUTPUT CODE WHILE COMPILING */
   CONTROL(BYTE('L')) = TRUE;
   CONTROL(BYTE('P'))=FALSE;  /* OUTPUT PRODUCTIONS */
   CONTROL(BYTE('R'))=FALSE; /* OUTPUT COMPILED CODE */
   CONTROL(BYTE('S'))=FALSE; /* OUTPUT FOR SYMBOL TABLE        */
   CONTROL(BYTE('T'))=FALSE;  /* OUTPUT PROCEDURE TABLE */
   CHARTYPE(BYTE('.'))=9;
   CHARTYPE(BYTE('/'))=7;
   CHARTYPE(125)=3;  /* SINGLE QUOTE */
   BUFFER1=INPUT;
   DO I=0 TO 126;  PRT(I),LAB(I)=0;  LAB(I+127),VCELL_ADDRESS(I)=0;  END;
```

```
      DO I=0 TO CONSIZE; CONSTANT1(I),CONSTANT2(I)=0; END;
      DO I= 0 TO 2876;  CODE(I)=0;  END;
      CODE(2)=4095;  CODE(3)=2;  CODE(4)=1;
      CONSTANT1(1)=SHL(4,12);  CONSTANT2(1)=1;
      CONSTANT1(2)=SHL(3,12);  CONSTANT2(2)=2;
      I=4095 MOD CONSIZE;  CONSTANT1(I)=SHL(2,12); CONSTANT2(I)=4095;
      CODE(5)=3712;  /* 7200 OCTAL */
      CODE(6)=3840;  /* 7400 OCTAL */
      CODE(7)=2944;  /* 5600 OCTAL */
      CODE(27)=2845;
      CODE(28)=2876; /* TAB ROUTINE */
      CODE(29)=2892; /* WRITE STRING ROUTINE */
      CODE(30)=2904; /* INTEGER WRITE ROUTINE */
      CODE(31)=2931; /* INTEGER READ ROUTINE */
      CODE(45),CODE(46)=4095; /* FLOATING POINT I/O INITIALIZATION */
      CODE(50)=3968; /* 7600 OCTAL ARRAY-SUBSCRIPTOR SUBPROGRAM */
      CODE(54)=4010; /* 7652 OCTAL-MULTIPLIER */
      CODE(55)=4028; /* 7674 OCTAL-DIVIDER */
      CODE(56)=1; CODE(57)=3072; /* NEG 1 IN FLOATING POINT */
      CODE(61)=4056; /* 7730 OCTAL-EXPONENTIATOR */
      DO I=0 TO 30;  CODE(I+2845)=FLOAT(I);  END;
      DO I=0 TO 27;  CODE(I+2876)=WRITE_STRING(I);  END;
      DO I=0 TO 39;  CODE(I+2904)=INTEGER_IO(I);  END;
      DO I=0 TO 127;  /* LOAD FLOATING POINT PACKAGE */
        CODE(I+2944)=A56(I);  CODE(I+3072)=A60(I);
        CODE(I+3200)=A62(I);  CODE(I+3328)=A64(I);
        CODE(I+3456)=A66(I);  CODE(I+3584)=A70(I);
        CODE(I+3712)=A72(I);  CODE(I+3840)=A74(I);  END;
      DO I=0 TO 109;  CODE(I+3968)=SUBPROGS(I);  END;
        /* SET INITIAL JUMP TO MAIN PROGRAM */
      CODE(128)=2945; /* JMP I 201 */  CODE(129)=130;  CB=CB+2;
    . CALL SCAN;

      /* INITIALIZE THE PARSE STACK */
      SP = 1;  PARSE_STACK(SP) = EOFILE;

   END INITIALIZATION;

DUMPIT:
   PROCEDURE;   /* DUMP OUT THE STATISTICS COLLECTED DURING THIS RUN  */
      DOUBLE_SPACE;
      /*  PUT OUT THE ENTRY COUNT FOR IMPORTANT PROCEDURES */
      OUTPUT = 'STACKING DECISIONS= ' || CALLCOUNT(1);
      OUTPUT = 'SCAN              = ' || CALLCOUNT(3);
      OUTPUT = 'FREE STRING AREA  = ' || FREELIMIT - FREEBASE;
   END DUMPIT;
```

```
STACK_DUMP:
   PROCEDURE;
      DECLARE LINE CHARACTER;
      LINE = 'PARTIAL PARSE TO THIS POINT IS: ';
      DO I = 2 TO SP;
         IF LENGTH(LINE) > 105 THEN
            DO; OUTPUT=LINE;
                LINE=X4;  END;
         LINE = LINE || X1 || V(PARSE_STACK(I));  END;
      OUTPUT = LINE;
   END STACK_DUMP;


  /*                    PROCEDURES FOR SYNTHESIZE                        */

ADVANCE_PAGE:
   PROCEDURE(N);
         /* SHIFT CODE GENERATION TO NEXT PAGE IF INSUFFICIENT ROOM
            AVAILABLE ON PRESENT ONE */
      DECLARE(N) FIXED;
      IF (CT-CB-N-AFLAG) < 1 THEN DO;
         IF AFLAG THEN DO; CODE(CB)= 0; /* FEXT */
                           CB=CB+1;  END;
         CODE(CB)=2944+CB+1-PAGE_BASE; /* 2944=56XX OCTAL, A JUMP */
         PAGE_BASE=PAGE_BASE+128;  CODE(CB+1)=PAGE_BASE;  CB=PAGE_BASE;
         CT=PAGE_BASE+127;
         DO I=0 TO AT;  VCELL_ADDRESS(I)=0;  END;  AT=0;
         IF AFLAG THEN DO; CODE(CB)=2311; /* JMS I 7 */ CB=CB+1;  END;  END;
   END ADVANCE_PAGE;

GET_ACELL:
   PROCEDURE(N) FIXED;
         /* RETURNS NEXT ARRAY CELL BLOCK, STARTING TOP PAGE 27 */
      DECLARE N FIXED;
      CA=CA-N;    RETURN CA;
   END GET_ACELL;

GET_PCELL:
   PROCEDURE FIXED;
         /* SETS CORE LOCATION FOR PROCEDURE M FROM 20 TO 36 OCTAL */
      IF PCELL=27 THEN DO; CALL ERROR('TOO MANY SUBPROGRAMS',2);
                           RETURN;     END;
      PCELL=PCELL+1;  RETURN PCELL-1;
   END GET_PCELL;

GET_TCELL:
   PROCEDURE (N,T) FIXED;
         /* RETURNS TEMPORARY STORAGE FROM PAGE ZERO DEPENDING ON
```

```
          WHETHER THAT LOCATION CONTAINS AN ADDRESS OR HOLDS A
          REAL OR INTEGER VALUE */
      DECLARE (N,T) FIXED;
      LOC(N)=T|SHL(TCELL,4);
      IF TCELL > PARMCELL THEN CALL ERROR
         ('PARAMETER STORAGE OVERLAYED,SEPARATE INTO ADDITIONAL STATEMENTS',2);
      IF T=1 THEN DO; TCELL=TCELL+3;
                      IF TCELL>MAXTCELL THEN MAXTCELL=TCELL;
                      RETURN TCELL-3;    END;
      IF TCELL+1 > MAXTCELL THEN MAXTCELL=TCELL+1;
      TCELL=TCELL+1;  RETURN TCELL-1;
   END GET_TCELL;

GET_VCELL:
   PROCEDURE(N) FIXED;
        /* RETURNS NEXT N CELLS FROM TOP OF PRESENT PAGE IF POSSIBLE */
      DECLARE N FIXED;
      ADVANCE(N+1);
      CT=CT-N;  RETURN CT+1;
   END GET_VCELL;


STORE_CODE:
   PROCEDURE (N) FIXED;
        /* STORE N IN NEXT AVAILABLE INSTRUCTION LOCATION OF CODE ARRAY
           RETURNS CODE LOCATION */
      DECLARE N FIXED;
      IF AFLAG THEN ADVANCE(2);
               ELSE ADVANCE(1);
      CODE(CB)=N;  CB=CB+1;  RETURN CB-1;
   END STORE_CODE;

AFLAG_CHECK:
   PROCEDURE;
        /* SETS AFLAG AND EMITS JMS TO INTREPTER IF AFLAG=0 */
      IF AFLAG=1 THEN RETURN;  ADVANCE(2);  AFLAG=1;
      IF CODE(CB-1)=4096 THEN CB=CB-1; /* REMAIN IN INTREPTER */
                         ELSE EMIT(2311); /* JMS I 7 */
   END AFLAG_CHECK;

EMIT_CHECK:
   PROCEDURE(OP,L);
        /* CHECK IF INDIRECT ADDRESSING REQUIRED: OP=OPERATION,LOC(L) */
      DECLARE(OP,L,P,M) FIXED;
      P=SHR(LOC(L),4);
      IF P<128 THEN DO;
        IF (LOC(L)&"4")>0 THEN EMIT(P|SHL(OP,9)|SHL(1,8));/* INDIRECT ADDRESS */
                          ELSE EMIT(P|SHL(OP,9)); /* DIRECT ADDRESS */
```

```
            RETURN;     END;
      IF(P >= PAGE_BASE) & (P < PAGE_BASE+128)
         THEN DO; M=(P-PAGE_BASE)|SHL(1,7); /* VARIABLE ON PRESENT PAGE */
                  EMIT(M|SHL(OP,9));  RETURN;  END;
      /* CHECK IF ADDRESS OF VARIABLE ON CURRENT PAGE */
      DO I=0 TO AT;
         IF (VCELL_ADDRESS(I)&"FFFF")=P THEN DO; P=SHR(VCELL_ADDRESS(I),16);
                                            M=(P-PAGE_BASE)|SHL(3,7);
                                            EMIT(M|SHL(OP,9));  RETURN;  END;  END;
      /* ENTER REFERENCE TO VARIABLE ON CURRENT PAGE AND INDIRECT ADDRESS */
      M=GET_VCELL(1);  CODE(M)=P;  VCELL_ADDRESS(AT)=SHL(M,16)|P;
      AT=AT+1;  M=M|SHL(3,7);  EMIT(M|SHL(OP,9));
   END EMIT_CHECK;

STORE_ASCII_CODE:
   PROCEDURE(N);
       /* CHECKS IF WRITE_STRING SUBPROGRAM STILL ENGAGED AND EMITS
          ASCII CHARACTER FOR TELETYPE OUTPUT */
      DECLARE N FIXED;
      IF CODE(CB-1)=4097 THEN DO; CB=CB-1;
                            ADVANCE(2);  END;
               ELSE DO; ADVANCE(3);
                            EMIT(2333); /* JMS I 35 */  END;
      EMIT(N);
      EMIT(4097); /* WEXT */
   END STORE_ASCII_CODE;

EMIT_ADDRESS:
   PROCEDURE(L,BACK);
       /* IF L CONTAINS AN ADDRESS LOAD THE ADDRESSED SPACE
          IN THE NEXT POSITION ELSE LOAD THE ADDRESS */
    . DECLARE(L,BACK,M) FIXED;
      M=SHR(LOC(L),4);
      IF (LOC(L)&"4")=0 THEN DO;EMIT(M);
                                RETURN; END;
      DO I=0 TO BACK-1;  CODE(CB-I+1)=CODE(CB-I-1);  END;
      CODE(CB-BACK)=512+M;  CODE(CB-BACK+1)=1664+CB-PAGE_BASE+2;
      IF BACK=2 THEN  IF CODE(CB-3)=(1664+CB-PAGE_BASE-1) THEN
            CODE(CB-3)=CODE(CB-3)+2;
      CB=CB+3;
   END EMIT_ADDRESS;

EMIT_STRING:
   PROCEDURE(C);
       /* OUTPUT STRING C */
       DECLARE C CHARACTER, (I,L,N) FIXED;
      DO I=0 TO LENGTH(C)-1;   N=BYTE(C);
         IF N=64 THEN EMITCAR(160); /* SPACE */
```

```
            ELSE IF N>192 & N<202 THEN EMITCAR(N); /* LETTER A - I */
            ELSE IF N>208 & N<218 THEN EMITCAR(N-7); /* LETTER J - R */
            ELSE IF N>225 & N<234 THEN EMITCAR(N-15); /* LETTER S - Z */
            ELSE IF N>239 & N<250 THEN EMITCAR(N-64); /* DECIMAL DIGIT */
            ELSE DO;
                        /* FORTRAN STRING CHARACTER | ::= "   */
                DO J=0 TO 14; /* CHECK FOR   " # $ % & ' ( ) * + , - . /   */
                  IF SUBSTR(C,0,1)=SUBSTR('¬|#$%&"()*+,-./' ,J,1)
                     THEN DO; EMITCAR(161+J);  GO TO FOUND;  END;  END;
                DO J=0 TO 6; /* CHECK FOR : ; < = > ? @  */
                  IF SUBSTR(C,0,1)=SUBSTR(':;<=>?@' ,J,1)
                     THEN DO; EMITCAR(186+J);  GO TO FOUND;  END;  END;
            CALL ERROR('ILLEGAL STRING SYMBOL '||SUBSTR(C,0,1),2);
            FOUND:  END;  C=SUBSTR(C,1);  END;
      END EMIT_STRING;

   STORE_CONSTANT:
      PROCEDURE(N1,N2,REQ) FIXED;
          /* STORE CONSTANT IN REQ NUMBER OF CELLS-RETURNS CODE LOCATION  */
         DECLARE(L,N1,N2,M,REQ) FIXED;
         IF (N1+N2)=0 THEN RETURN 58; /* ZERO CONSTANT CORE LOCATION */
         L=(N1+N2) MOD CONSIZE;
         DO FOREVER;
            IF CONSTANT2(L)=N2
               THEN IF (CONSTANT1(L) & "FFF")=N1
                  THEN RETURN SHR(CONSTANT1(L),12);
            IF CONSTANT2(L) + CONSTANT1(L)=0 THEN GO TO ENTER;
            IF L=CONSIZE THEN L=0;
                         ELSE L=L+1;  END;
       ENTER:  /* CONSTANT NOT LOCATED - INSERT CONSTANT */
         M=GET_VCELL(REQ);  CONSTANT2(L)=N2;
         CONSTANT1(L )=N1 | SHL(M,12);
         IF REQ>1 THEN DO; CODE(M)=N1 & "FFF";  CODE(M+1)=SHR(N2,12);
                           CODE(M+2)=N2 & "FFF";  END;
                  ELSE CODE(M)=N2 & "FFF";
         RETURN M;
      END STORE_CONSTANT;


   SET:
      PROCEDURE(C) FIXED;
          /* RETURN BASED ON I THRU N BEING INTEGERS
             INTEGER=0  , REAL=1    */
         DECLARE C CHARACTER, K FIXED;
         K=BYTE(C);
         IF (K > 200) & (K < 214) THEN RETURN 0; /* AN INTEGER */
                                  ELSE RETURN 1; /* A REAL */
      END SET;
```

```
HASH:
   PROCEDURE(C,L) FIXED;
         /* L= NUMBER OF CHARACTERS IN C
                RETURNS ENTRY INTO HASH SECTION OF PRT  */
      DECLARE C CHARACTER, (I,K,L) FIXED;
      K=L;    I=0;
      DO WHILE (I <= 2) & (I < L);  K=SHL(K,8)|BYTE(C,I);  I=I+1;  END;
      RETURN K MOD 127;
   END HASH;

LOOKUP:
   PROCEDURE (C) FIXED;
         /* FIND IDENTIFIER C AND RETURN PRT LOCATION */
      DECLARE C CHARACTER, (N,L) FIXED;
      L=HASH(C,LENGTH(C));
      IF PRT(L)=0 THEN RETURN 0;  L=PRT(L);
      DO FOREVER;
         IF SYMBOL(PRT(L) & "FF")=C THEN DO; TYPE=SHR(PRT(L),30);
                                             PARM=SHR(SHL(PRT(L),2),31);
                                             RETURN L;  END;
         L=SHR(SHL(PRT(L),3),23);
         IF PRT(L)=0 THEN RETURN 0;  END;
   END LOOKUP;

ENTER:
   PROCEDURE (C,T) FIXED;
         /* C IS IDENTIFIER OF TYPE T TO ENTER IN PRT, RETURNS PRT LOCATION */
      DECLARE C CHARACTER, (L,M,N,T) FIXED;
      N=LENGTH(C);
      IF N > 6 THEN
         DO; OUTPUT='* * * WARNING * * *';
             CALL ERROR('IDENTIFIER LENGTH EXCEEDS 6 CHARACTERS',0);
             C=SUBSTR(C,0,6);  END;
      IF ST>255 THEN CALL ERROR('SYMBOL TABLE LIMIT EXCEEDED',2);
      L=HASH(C,N);
      IF PRT(L)=0 THEN DO; ST=ST+1;  PRT(L)=PT;  PRT(PT)=ST | SHL(T,30);
                           SYMBOL(ST)=C;  PT=PT+1;  TYPE=T;
                           IF TYPE=0 THEN SIZE(ST)=1;
                                     ELSE SIZE(ST)=3;
                           RETURN PT-1;  END;
      L=PRT(L); /* A COLLISION OCCURRED */
      DO FOREVER;
         M=SHR(SHL(PRT(L),3),23);
         IF M=0 THEN DO; PRT(L)=PRT(L) | SHL(PT,20);  ST=ST+1;
                         PRT(PT)=ST | SHL(T,30);  SYMBOL(ST)=C;
                         PT=PT+1;  TYPE=T;
                         IF TYPE=0 THEN SIZE(ST)=1;
```

```
                                          ELSE SIZE(ST)=3;
                               RETURN PT-1;  END;
         L=M;   END;
   END ENTER;

ENTER1:
   PROCEDURE(C,N) FIXED;
         /* ENTERS VARIABLE IN PRT AND GETS CODE STORAGE FOR THAT VARIABLE
           RETURNS CODE LOCATION */
      DECLARE C CHARACTER, (L,M,N) FIXED;
      M=ENTER(C,SET(C));
      IF SHR(PRT(M),30)=1 THEN DO; L=GET_VCELL(3); LOC(N)=SHL(L,4)|1; END;
                             ELSE DO; L=GET_VCELL(1); LOC(N)=SHL(L,4)|0; END;
      PRT(M)=PRT(M) | SHL(L,8);
      RETURN M;
   END ENTER1;

COMMON_CHECK:
   PROCEDURE(L);
        /* RELOCATES VARIABLES INTO COMMON SECTION OF PRT
           L REFERS TO STACKSIZE POINTER (MP TO SP) */
      DECLARE(L,M,P) FIXED;
      P=LOOKUP(VAR(L));
      IF P=0 THEN
         DO; CALL ERROR('COMMON VARIABLE: '||VAR(L)||' ,MUST BE KNOWN',2);
            OUTPUT='**PLACE VARIABLE IN A DECLARATION STATEMENT';  END;
      IF P<147 THEN RETURN;  /* ALREADY RELOCATED */
      IF SC>19 THEN CALL ERROR('EXCESSIVE COMMON VARIABLES',2);    M=-1;
      DO I=0 TO 126;  /* LOCATE HASH ENTRY */
         IF PRT(I)=P THEN M=I;  END;
      IF M=-1 THEN DO;
         CALL ERROR('COMMON VARIABLE: '||VAR(L)||' ,CANNOT BE RELOCATED',2);
         M=HASH(VAR(L),LENGTH(VAR(L)));
         OUTPUT='***RENAME VARIABLE: '||PSYMBOL(PRT(PRT(M))&"FF");  END;
      PRT(M)=SC+127;  SYMBOL(SC)=VAR(L);
      SYMBOL(PRT(P) & "FF")='ZZZZZZZ'; /* RETAIN FOR COLLISION */
      PRT(SC+127)=(PRT(P) & "E00FFF00") +SC;  SIZE(SC)=SIZE(P-127);  SC=SC+1;
      PRT(P)=PRT(P) &"1FF000FF";
   END COMMON_CHECK;


FIND_PROC:
   PROCEDURE(C) FIXED;
        /* LOCATE IDENTIFIER C IN PROCEDURE TABLE - RETURNS LOCATION */
      DECLARE C CHARACTER, I FIXED;
      DO I=1 TO PC;  IF PSYMBOL(I)=C THEN RETURN I;  END;
      RETURN 0;
   END FIND_PROC;
```

```
SET_PROC:
   PROCEDURE(C,T) FIXED;
         /* PLACE IDENTIFIER C OF TYPE T IN PROCEDURE TABLES-RETURNS LOCATION */
      DECLARE C CHARACTER, T FIXED;
      PSYMBOL(PC)=C;   PTABLE(PC)=SHL(T,29) | SHL(GET_PCELL,12);
      PTABLE(PC)=PTABLE(PC) | PARMCELL;   PC=PC+1;   RETURN PC-1;
   END SET_PROC;


FIND_LABEL:
   PROCEDURE (N) FIXED;
         /* ENSURES ENTRY FOR LABEL N IN LABEL ARRAY
            RETURNS LOCATION IN LABEL ARRAY */
      DECLARE(L,CNT,N) FIXED;
      IF N=0 THEN CALL ERROR('LABEL ZERO CANNOT BE USED',2);
      L=N MOD 127;    CNT=0;
      DC FOREVER;
         IF (L=0) | (L=127) THEN L=1;
         IF LAB(L)=0 THEN DO; LAB(L)=N;  RETURN L;  END;
         IF LAB(L)=N THEN RETURN L;
         L=L+1;    CNT=CNT+1;
         IF CNT=127 THEN CALL ERROR('EXCESSIVE LABELS',2);  END;
   END FIND_LABEL;

SETLAB:
   PROCEDURE(L,POSITION) FIXED;
         /* RETURNS RELATIVE POSITION OF CODE WITHIN PRESENT PAGE
            WHERE FUTURE LABEL INSERTIONS SHALL BE MADE */
      DECLARE(L,POSITION,M) FIXED;
      ADVANCE(2);  M=GET_VCELL(1);
      CODE(M)=SHL(L,16) | POSITION;
      RETURN M-PAGE_BASE;
   END SETLAB;


SUBSCRIPT:
   PROCEDURE(T,L) FIXED;
         /* COMPUTE SUBSCRIPT OF ARRAY IN CODE BLOCK WITH BASE L OF TYPE T
            SUBSCRIPTS PASSED IN DIM ARRAY */
      DECLARE(L,N,T,SUM) FIXED;
      DT=DT+1;
      N=4096 - CODE(L); /* NUMBER OF DIMENSIONS */
      IF T<3 THEN T=1; /* INTEGER ARRAY ELSE REAL ARRAY */
      SUM=N+1+DIM(DT+N-1)*T+L-CODE(L+N);
      DT=DT+1;
      IF N=3 THEN DO;  SUM=SUM+(DIM(DT)*CODE(L+1)+DIM(DT-1)*CODE(L+2))*T;
                       DT=DT+2;  END;
```

```
               ELSE IF N=2 THEN DO; SUM=SUM+(DIM(DT-1)*T*CODE(L+1));
                                    DT=DT+1;   END;
          RETURN SUM;
     END SUBSCRIPT;

INSERT_CHECK:
     PROCEDURE(T);
          /* CHECKS DATA INPUT FOR ASSIGNMENT COMPATABILITY */
        DECLARE(T) FIXED;
        IF FIXM(MP+1) > 0 THEN DO; IF T=1 THEN RETURN;  END;
                              ELSE DO; IF T=0 THEN RETURN;  END;
        CALL ERROR('VARIABLE AND NUMBER TYPE MUST AGREE',2);
     END INSERT_CHECK;

INSERT_DATA:
     PROCEDURE;
          /* INSERT DATA INTO PREVIOUSLY SAVED VARIABLES OF DIM ARRAY */
        DECLARE L FIXED;
        DIM(0)=DIM(0)+"100"; /* NUMBER COUNTER */
        TYPE=DIM(DT) & "F";
        L=SHR(DIM(DT),8); /* CORE LOCATION */
        DO CASE TYPE;
           /* CASE 0 INTEGER VARIABLE */
           DO; CODE(L)=FIXV(MP+1);  DT=DT+1;  CALL INSERT_CHECK(TYPE);  END;
           /* CASE 1 REAL VARIABLE  */
           DO; CALL INSERT_CHECK(TYPE);  GO TO INSERT_REAL;  END;
           /* CASE 2 INTEGER ARRAY */
           DO; L=SUBSCRIPT(TYPE,L);  CALL INSERT_CHECK(TYPE-2);
               CODE(L)=FIXV(MP+1);   END;
           /* CASE 3 REAL ARRAY */
           DO; L=SUBSCRIPT(TYPE,L);  CALL INSERT_CHECK(TYPE-2);
          INSERT_REAL:  CODE(L+1)=SHR(FIXM(MP+1),12) & "FFF";
           CODE(L)=FIXV(MP+1);  CODE(L+2)=(FIXM(MP+1) & "FFF");  END;  END;
     END INSERT_DATA;


DUMPING:
     PROCEDURE(FROM,LAST);
          /* OUTPUT PRT CELLS FROM TO LAST */
        DECLARE B CHARACTER, (FROM,I,J,LAST,M,N,P) FIXED;  B='              ';
        DO I=FROM TO LAST;
           OUTPUT=' '; IF SYMBOL(I)¬='ZZZZZZZ'  THEN DO; P=LOOKUP(SYMBOL(I));
           M=READ_OCTAL(SHR(PRT(P) & "FFF00",8)); /* LOCATION */
           IF TYPE>1 & PARM=0 THEN N=4096-CODE(SHR(PRT(P) & "FFF00",8));
                              ELSE N=0;
           OUTPUT='    '|| SYMBOL(I) ||B|| I ||B|| M ||B|| PARM || B ||
             SHR(SHL(PRT(P),3),23)||B||TYPE||B||N||B||P||B||SIZE(P-127);  END;
     END;
```

```
      END DUMPING;

   DUMP:
      PROCEDURE;
           /* LIST PRT AND SYMBOL TABLE ENTRIES */
         DOUBLE_SPACE;
         OUTPUT='* * * COMBINED PRT/SYMBOL TABLE DUMP * * *';  OUTPUT=' ';
         OUTPUT='IDENTIFIER       SYMBOL#     BASE       PARAMETER      '||
               'COLLISION      TYPE      #DIM      PRT LOCATION     CELLS';
         CALL DUMPING(0,SC-1);
         CALL DUMPING(20,ST);
      END DUMP;

    /*                    THE SYNTHESIS ALGORITHM FOR XPL                        */


   SYNTHESIZE:
   PROCEDURE(PRODUCTION_NUMBER);
      DECLARE PRODUCTION_NUMBER FIXED;
         DECLARE (H,I,M,N,P,Z) FIXED;
      /*  THIS PROCEDURE IS RESPONSIBLE FOR THE SEMANTICS (CODE SYNTHESIS), IF
         ANY, OF THE SKELETON COMPILER.  ITS ARGUMENT IS THE NUMBER OF THE
         PRODUCTION WHICH WILL BE APPLIED IN THE PENDING REDUCTION.  THE GLOBAL
         VARIABLES MP AND SP POINT TO THE BOUNDS IN THE STACKS OF THE RIGHT PART
         OF THIS PRODUCTION.
          NORMALLY, THIS PROCEDURE WILL TAKE THE FORM OF A GIANT CASE STATEMENT
         ON PRODUCTION_NUMBER.  HOWEVER, THE SYNTAX CHECKER HAS SEMANTICS (THE
         TERMINATION OF CHECKING) ONLY FOR PRODUCTION 1.                      */
     DO CASE PRODUCTION_NUMBER;
    /*  PRODUCTION ZERO   */
      ;
    /* .<MASTER PROGRAM> ::= <PROGRAM>      */
      DO;IF MAXTCELL > PARMCELL THEN CALL ERROR
           ('PARAMETER STORAGE OVERLAYED BY TEMPORARY CELLS',2);
         IF CONTROL(BYTE('T')) THEN DO;   DOUBLE_SPACE;
         OUTPUT='  '; OUTPUT='* * * PROCEDURE TABLE * * *'; OUTPUT='  ';
         OUTPUT=' PROCEDURE NAME    TYPE     INCLUDED=1     #PARAMETERS'||
          '         PARAMETER BASE         CORE LOCATION';
         DO I=1 TO PC-1;  M=SHR(SHL(PTABLE(I),4),28);
            IF M=0 THEN N=0;  ELSE N=SHR(SHL(PTABLE(I),20),20);
            OUTPUT='   ';  OUTPUT='      '||PSYMBOL(I)||'         '||
            SHR(PTABLE(I),29)||'             '||SHR(SHL(PTABLE(I),3),31)||
            '               '||M||'                   '||N||'                 '||
            READ_OCTAL(SHR(SHL(PTABLE(I),8),20));  END;  END;
         COMPILING=FALSE;  DOUBLE_SPACE;
         IF STOP THEN CALL ERROR('STOP STATEMENT MISSING IN MAIN PROGRAM',0);
         IF BEGIN=0 THEN CALL ERROR('MISSING MAIN PROGRAM',2);
         N=CONTROL(BYTE('C'));     EP=0;
```

```
      IF N THEN OUTPUT='LOCATION     CODE';
      DO I=0 TO PAGE_BASE+127;
         M=CODE(I);
         IF M=4096 | M=4097 THEN CODE(I)=0; /* RESET FEXT & WEXT INSTRUCTIONS */
         IF N THEN OUTPUT='    '||READ_OCTAL(I)||'       '||READ_OCTAL(CODE(I));
         IF CODE(I)>4095 THEN CALL ERROR('CODE EMISSION ERROR',2);   END;
      DO I=PAGE_BASE+128 TO 2845;
         IF CODE(I)>4095 THEN CALL ERROR('CODE EMISSION ERROR',2);
         IF N & CODE(I) ¬= 0 THEN OUTPUT='    '||READ_OCTAL(I)||'        '||
            READ_OCTAL(CODE(I));   END;   END;

/*  <PROGRAM> ::= <STATEMENT BLOCK> END ;     */
  DO;
   PROG:
      DO I=PAGE_BLOCK TO PAGE_BASE+127; /* BACKSTUFF LABELS */
         M=SHR(CODE(I),16);
         IF M¬=0 THEN DO;
            IF  LAB(M+127)<2 THEN CALL ERROR('MISSING LABEL '||LAB(M),1);
            IF (CODE(I)&"1")=0 THEN N=SHR(LAB(M+127),16); /* FRONT */
                                ELSE N=LAB(M+127)&"FFFF"; /* REAR */
            CODE(I)=N;  END;  END;
      PAGE_BLOCK=CB;
      IF CB > 2944 THEN CALL ERROR
         ('PROGRAM TOO LARGE. ARRAYS AND FLOATING POINT PACKAGE OVERLAYED',0);
      IF CONTROL(BYTE('S')) THEN CALL DUMP;
      DO I=0 TO 126;
        LAB(I),LAB(I+127)=0;  IF PRT(I)>146 THEN PRT(I)=0;  END;
      ST=19;  PT=147;  EJECT_PAGE;  END;

/*  <PROGRAM> ::= <PROGRAM> <STATEMENT BLOCK> END ;    */
      GO TO PROG;

/*  <STATEMENT BLOCK> ::= <STATEMENT LIST>    */
  BEGIN=1;

/*  <STATEMENT BLOCK> ::= <DECLARATION LIST> <STATEMENT LIST>    */
  BEGIN=1;

/*  <STATEMENT BLOCK> ::= <PROCEDURE BLOCK> <STATEMENT LIST>   */
  DO; IF BEGIN=0 THEN CODE(129)=CB;       SFLAG=0;
      IF RFLAG THEN CALL ERROR('MISSING RETURN',2);  END;

/*  <STATEMENT LIST> ::= <STATEMENT> ;    */
  TCELL=62;

/*  <STATEMENT LIST> ::= <STATEMENT LIST> <STATEMENT> ;    */
  TCELL=62;
```

```
/*  <STATEMENT> ::= <IF STATEMENT>     */
  ;

/*  <STATEMENT> ::= <BASIC STATEMENT>     */
  ;

/*  <STATEMENT> ::= <DO STATEMENT>     */
  ;

/*  <STATEMENT> ::= <LABELED STATEMENT>     */
  ;

/*  <BASIC STATEMENT> ::= <ASSIGNMENT STATEMENT>     */
  ;

/*  <BASIC STATEMENT> ::= <GO STATEMENT>     */
  ;

/*  <BASIC STATEMENT> ::= <SUBROUTINE CALL>     */
  ;

/*  <BASIC STATEMENT> ::= <READ STATEMENT>     */
  ;

/*  <BASIC STATEMENT> ::= <WRITE STATEMENT>     */
  ;

/*  <BASIC STATEMENT> ::= RETURN     */
   DO;M=ENTRY & "FFFF"; /* PROCEDURE ENTRY POINT */
      IF (M >= PAGE_BASE) & (M < PAGE_BASE+128) THEN N=1;
       /* IF N=1 THEN ENTRY ON PRESENT PAGE */  ELSE N=0;
      IF SHR(ENTRY,16)=0 THEN
              DO; IF N=1 THEN EMIT(2944+M-PAGE_BASE); /* JMP I */
                         ELSE DO; ADVANCE(4);
                                  EMIT(896+CB-PAGE_BASE+3); /* TAD I */
                                  EMIT(1664+CB-PAGE_BASE+2); /* DCA */
                                  EMIT(2944+CB-PAGE_BASE+1); /* JMP I */
                                  CODE(CB)=M;  CB=CB+1;  END;
                  RFLAG=0;  RETURN;  END;
         /* ELSE MUST RETURN FUNCTION VARIABLE ADDRESS DURING RETURN */
      IF N=1 THEN DO; ADVANCE(3);
                      EMIT(896+CB-PAGE_BASE+2); /* TAD */
                      EMIT(2944+M-PAGE_BASE); /* JMP I */
                      CODE(CB)=SHR(ENTRY,16); CB=CB+1;   END;
              ELSE DO; ADVANCE(6);
                      EMIT(896+CB-PAGE_BASE+4); /* TAD I ENTRY */
                      EMIT(1664+CB-PAGE_BASE+3); /* DCA */
                      EMIT(640+CB-PAGE_BASE+3); /* TAD FUNCTION ADDRESS */
```

```
                          EMIT(2944+CB-PAGE_BASE+1); /* JMP I */
                          CODE(CB)=M;  CB=CB+2;
                          CODE(CB-1)=SHR(ENTRY,16);   END;
    RFLAG=0;  END;

/*  <BASIC STATEMENT> ::= STOP    */
  DO;EMIT(3842); /* HLT */
    IF SFLAG=0 THEN STOP=0;  END;

/*  <IF STATEMENT> ::= <ARITHMETIC IF> <DOUBLE LABEL> <NUMBER>     */
  DO;IF (LOC(MP)&"1")=1 THEN DO; ADVANCE(4);
                                 EMIT(2311); /* JMS I 7 */
                                 EMITCK(5,MP); /* FGET */
                                 EMIT(0000); /* FEXT */
                                 EMIT(549); /* TAD 45 */
                                 P=GET_TCELL(MP,1);
                                 EMIT(1536+P); /* DCA */  END;
                            ELSE EMITCK(1,MP); /* TAD */
    ADVANCE(5);
    EMIT(4032); /* SMA CLA */
    EMIT(2688+CB-PAGE_BASE+3); /* JMP I */
    EMIT(2944+CB-PAGE_BASE+1); /* JMP I */
    CODE(CB)=LOC(MP+1)&"FFFF0000"; /* EXPRESSION < ZERO */
    CB=CB+1;
    EMITCK(1,MP); /* TAD */
    ADVANCE(5);
    EMIT(4000); /* SZA CLA */
    EMIT(2944+CB-PAGE_BASE+3); /* JMP I */
    EMIT(2944+CB-PAGE_BASE+1); /* JMP I */
    CODE(CB)=SHL(LOC(MP+1),16); /* EXPRESSION = ZERO */
    CODE(CB+1)=SHL(FIND_LABEL(FIXV(SP)),16); /* EXPRESSION > ZERO */
    CB=CB+2;  END;

/*  <IF STATEMENT> ::= <LOGICAL IF> <BASIC STATEMENT>     */
    CODE(LOC(MP))=CB;

/*  <ARITHMETIC IF> ::= <IF> <EXPRESSION>     */
    LOC(MP)=LOC(MP+1);

/*  <IF> ::= IF (     */
  ;

/*  <DOUBLE LABEL> ::= ) <LABEL1> <LABEL1>     */
    LOC(MP)=SHL(LOC(MP+1),16) | LOC(SP);

/*  <LABEL1> ::= <NUMBER> ,     */
  LOC(MP)=FIND_LABEL(FIXV(MP));
```

```
/*  <EXPRESSION> ::= <TERM>     */
     IF AFLAG THEN DO; EMIT(4096); /* FEXT */
                       AFLAG=0;  END;

/*  <EXPRESSION> ::= <EXPRESSION> + <TERM>     */
  DO;Z=(LOC(MP) & "1") + (LOC(SP) & "1");
     DO CASE Z;
        /* CASE 0 BOTH INTEGERS */
        DO; EMITCK(1,MP); /* TAD */
            EMITCK(1,SP); /* TAD */
            P=GET_TCELL(MP,0);
            EMIT(1536+P); /* DCA */    END;
        /* CASE 1 ILLEGAL */
        CALL ERROR('ARITHMETIC TYPE INCOMPATABLE',2);
        /* CASE 2 BOTH REAL */
        DO; AFLAGCK;
            EMITCK(5,MP); /* FGET */
            EMITCK(1,SP); /* FADD */
            P=GET_TCELL(MP,1);
            EMIT(3072+P); /* FPUT */
            EMIT(4096); /* FEXT */  AFLAG=0;  END;  END;  END;

/*  <EXPRESSION> ::= <EXPRESSION> - <TERM>     */
  DO;Z=(LOC(MP) & "1") + (LOC(SP) & "1");
     DO CASE Z;
        /* CASE 0 BOTH INTEGERS */
        DO; EMITCK(1,SP); /* TAD */
            EMIT(3616); /* CMA */
            EMIT(516); /* TAD 4 */
            EMITCK(1,MP); /* TAD */
            P=GET_TCELL(MP,0);
            EMIT(1536+P); /* DCA */    END;
        /* CASE 1 ILLEGAL */
        CALL ERROR('ARITHMETIC TYPE INCOMPATABLE',2);
        /* CASE 2 BOTH REAL */
        DO; AFLAGCK;
            EMITCK(5,MP); /* FGET */
            EMITCK(2,SP); /* FSUB */
            P=GET_TCELL(MP,1);
            EMIT(3072+P); /* FPUT */
            EMIT(4096); /* FEXT */  AFLAG=0;  END;  END;  END;

/*  <EXPRESSION> ::= + <TERM>     */
  DO;LOC(MP)=LOC(MP+1);  EMIT(4096); /* FEXT */  AFLAG=0;  END;

/*  <EXPRESSION> ::= - <TERM>     */
  DO;IF (LOC(SP) & "1")=0
        THEN DO; EMITCK(1,SP); /* TAD */
```

```
                EMIT(3616); /* CMA */
                EMIT(516); /* TAD 4 */
                P=GET_TCELL(MP,0);
                EMIT(1536+P); /* DCA */   END;
            DO; AFLAGCK;
                EMIT(2618); /* FGET 72 */
                EMITCK(2,SP); /* FSUB */
                P=GET_TCELL(MP,1);
                EMIT(3072+P); /* FPUT */
                EMIT(4096); /* FEXT */  AFLAG=0;  END;  END;

/*  <TERM> ::= <PRIMARY>     */
  ;

/*  <TERM> ::= <PRIMARY*> <PRIMARY>     */
  DO;Z=(LOC(MP) & "1") + (LOC(SP) & "1");
     DO CASE Z;
        /* CASE 0 BOTH INTEGERS */
        DO; ADVANCE(7);
            EMIT(2358); /* JMS I 66 */
            EMITA(MP,1); /* ADDRESS */
            EMITA(SP,2); /* ADDRESS */
            P=GET_TCELL(MP,0);
            EMIT(1536+P); /* DCA */   END;
        /* CASE 1 ILLEGAL */
        CALL ERROR('ARITHMETIC TYPE INCOMPATABLE',2);
        /* CASE 2 BOTH REAL */
        DO; AFLAGCK;
            EMITCK(5,MP); /* FGET */
            EMITCK(3,SP); /* FMPY */
            P=GET_TCELL(MP,1);
            EMIT(3072+P); /* FPUT */  END;  END;  END;

/*  <TERM> ::= <TERM> / <PRIMARY>     */
  DO;Z=(LOC(MP) & "1") + (LOC(SP) & "1");
     DO CASE Z;
        /* CASE 0 BOTH INTEGERS */
        DO; ADVANCE(7);
            EMIT(2359); /* JMS I 67 */
            EMITA(MP,1); /* ADDRESS */
            EMITA(SP,2); /* ADDRESS */
            P=GET_TCELL(MP,0);
            EMIT(1536+P); /* DCA */   END;
        /* CASE 1 ILLEGAL */
        CALL ERROR('ARITHMETIC TYPE INCOMPATABLE',2);
        /* CASE 2 BOTH REAL */
        DO; AFLAGCK;
            EMITCK(5,MP); /* FGET */
```

```
                EMITCK(4,SP); /* FDIV */
                P=GET_TCELL(MP,1);
                EMIT(3072+P); /* FPUT */  END;  END;  END;

/*  <PRIMARY> ::= <SECONDARY>     */
  ;

/*  <PRIMARY> ::= <PRIMARY*> * <SECONDARY>     */
  DO;IF (LOC(SP) &"1")=1 THEN CALL ERROR
        ('EXPONENT MUST EVALUATE TO AN INTEGER',2);
     IF (LOC(MP) & "1")=0 THEN DO;
        IF (TCELL+2) > PARMCELL THEN CALL ERROR
           ('CODE BEING OVERLAYED. SEPARATE INTO ADDITIONAL STATEMENTS',2);
        EMITCK(1,SP); /* TAD */
        EMIT(3616); /* CMA */
        EMIT(516); /* TAD 4 */
        EMIT(1536+TCELL+1); /* DCA */
        EMITCK(1,MP); /* TAD */
        EMIT(1536+TCELL); /* DCA */
        ADVANCE(8);
        LOC(MP+1)=SHL(CB,4); /* SAVE NEXT ADDRESS */
        EMIT(2358); /* JMS I 66 */
        EMITA(MP,1); /* ADDRESS */
        EMIT(TCELL); /* ADDRESS */
        EMIT(1536+TCELL); /* DCA */
        EMIT(1024+TCELL+1); /* ISZ */
        EMIT(2688+CB-PAGE_BASE-5); /* JMP */
        CALL GET_TCELL(MP,0);   END;
       ELSE DO;
        IF AFLAG THEN DO; CODE(CB)=0; /* FEXT */
                          CB=CB+1;  AFLAG=0;  END;
        ADVANCE(7);
        EMIT(2365); /* JMS 75 */
        EMITA(SP,1); /* EXPONENT ADDRESS */
        EMITA(MP,2); /* NUMBER ADDRESS */
        P=GET_TCELL(MP,1);
        AFLAGCK;
        EMIT(3072+P); /* FPUT */  END;  END;

/*  <PRIMARY*> ::= <SECONDARY> *    */
  ;

/*  <SECONDARY> ::= <VARIABLE>    */
  IF LOOKUP(VAR(MP))=0 THEN
     DO; IF VAR(MP+1)=BYTE('=') THEN RETURN;
         IF FIND_PROC(VAR(MP)) > 0 THEN RETURN;
         CALL ERROR('UNKNOWN VARIABLE:  '||VAR(MP),2);  END;
```

```
/*  <SECONDARY> ::= <NUMBER>     */
  DO;IF DFLAG¬=3 THEN RETURN;
     IF FIXM(MP)=0 THEN DO; /* NUMBER LESS THAN 12 BITS */
                         P=STORE_CONSTANT(0,FIXV(MP),1);
                         LOC(MP)=SHL(P, 4) | 0;  END;
             ELSE DO;  P=STORE_CONSTANT(FIXV(MP),(FIXM(MP)&"FFFFFF"),3);
                         LOC(MP)=SHL(P, 4) | 1;  END;  END;

/*  <SECONDARY> ::= ( <EXPRESSION> )     */
  LOC(MP)=LOC(MP+1);

/*  <SECONDARY> ::= ABS ( <EXPRESSION> )     */
  IF (LOC(SP) & "1")=0 THEN
        DO; EMITCK(1,SP-1); /* TAD */
            ADVANCE(3);
            EMIT(3912); /* SPA */
            EMIT(3616); /* CMA */
            P=GET_TCELL(MP,0);
            EMIT(1536+P); /* DCA */  END;
        ELSE DO; AFLAGCK;
                 ADVANCE(3);
                 EMITCK(5,SP-1); /* FGET */
                 P=GET_TCELL(MP,1);
                 EMITCK(6,MP); /* FPUT */
                 EMIT(0000); /* FEXT */
                 EMIT(512+P+1); /* TAD */
                 EMIT(3904); /* SMA */
                 ADVANCE(5);
                 EMIT(2688+CB-PAGE_BASE+4); /* JMP */
                 EMIT(3588); /* RAL */
                 EMIT(3648); /* CLL */
                 EMIT(3592); /* RAR */
                 EMIT(1536+P+1); /* DCA */  END;

/*  <SECONDARY> ::= SQR ( <EXPRESSION> )     */
  DO;IF (LOC(SP) & "1")=0 THEN CALL ERROR
        ('SQR REQUIRES REAL EXPRESSION',2);
     AFLAGCK;
     EMITCK(5,SP-1); /* FGET */
     EMIT(0001); /* SQR */
     P=GET_TCELL(MP,1);
     EMITCK(6,MP); /* FPUT */  END;

/*  <SECONDARY> ::= SQRT ( <EXPRESSION> )     */
  DO;IF (LOC(SP) & "1")=0 THEN CALL ERROR
        ('SQRT REQUIFES PEAL EXPRESSION',2);
     AFLAGCK;
     EMITCK(5,SP-1); /* FGET */
```

```
      EMIT(0002); /* SQRT */
      P=GET_TCELL(MP,1);
      EMITCK(6,MP); /* FPUT */  END;

/*  <SECONDARY> ::= FLOAT ( <EXPRESSION> )    */
   DO;IF (LOC(SP-1) & "1")=1 THEN
         DO; CALL ERROR('EXPRESSION ALREADY DECLARED REAL',0);
             RETURN;  END;
      EMITCK(1,SP-1); /* TAD */
      EMIT(2331); /* JMS I 33 */
      AFLAGCK;
      CALL GET_TCELL(MP,1);
      EMITCK(6,MP); /* FPUT */  END;

/*  <LOGICAL IF> ::= <IF> <BOOLEAN EXPRESSION> )     */
   DO;EMIT(512+LOC(MP+1)); /* TAD */
      EMIT(514); /* TAD 2 */
      P=GET_VCELL(1);
      LOC(MP)=P; /* SAVE ADDRESS FOR JMP */
      ADVANCE(3);
      EMIT(4000); /* SZA CLA */
      EMIT  (2944+P-PAGE_BASE); /* JMP */
      TCELL=62;  END;

/*  <BOOLEAN EXPRESSION> ::= <BOOLEAN TERM>     */
   ;

/*  <BOOLEAN EXPRESSION> ::= <BOOLEAN EXPRESSION> .OR. <BOOLEAN TERM>     */
   DO;EMIT(512+LOC(MP)); /* TAD */
      EMIT(3857); /* MQL */
      EMIT(512+LOC(SP)); /* TAD */
      EMIT(3905); /* MQA */
      EMIT(1536+LOC(MP));  END;

/*  <BOOLEAN TERM> ::= <BCOLEAN PRIMARY>     */
   ;

/*  <BOOLEAN TERM> ::= .NOT. <BOOLEAN PRIMARY>     */
   DO;LOC(MP)=LOC(MP+1);
      EMIT(512+LOC(MP)); /* TAD */
      EMIT(514); /* TAD */
      EMIT(4000); /* SZA CLA */
      EMIT(3713); /* CLA IAC */
      EMIT(1536+LOC(MP)); /* DCA */  END;

/*  <BOOLEAN TERM> ::= <BOOLEAN TERM> .AND. <BCOLEAN PRIMARY>     */
   DO;EMIT(512+LOC(MP)); /* TAD */
      EMIT(LOC(SP)); /* AND */
```

```
      EMIT(1536+LOC(MP)); /* DCA */  END;
/*  <BOOLEAN PRIMARY> ::= <LOGICAL EXPRESSION>     */
  ;
/*  <BOOLEAN PRIMARY> ::= ( <BOOLEAN EXPRESSION> )     */
  LOC(MP)=LOC(MP+1);
/*  <LOGICAL EXPRESSION> ::= <EXPRESSION> <RELATION> <EXPRESSION>     */
  DO;Z=(LOC(MP) & "1") + (LOC(SP) & "1");
      IF LOC(MP+1)>2 THEN DO; M=LOC(SP); LOC(SP)=LOC(MP); LOC(MP)=M; END;
      EMIT(3776); /* CLA CLL */
      DO CASE Z;
         /* CASE 0 BOTH INTEGERS */
         DO; EMITCK(1,SP); /* TAD */
             EMIT(3616); /* CMA */
             EMIT(516); /* TAD 4 */
             EMITCK(1,MP); /* TAD */   END;
         /* CASE 1 ILLEGAL */
         CALL ERROR('RELATION REQUIRES ARITHMETIC TYPE COMPATABILITY',2);
         /* CASE 2 BOTH REAL */
         DO; ADVANCE(6);
             EMIT(2311); /* JMS I 7 */
             EMITCK(5,MP); /* FGET */
             EMITCK(2,SP); /* FSUB */
             EMIT(0000); /* FEXT */
             EMIT(549); /* TAD 45 */   END;   END;
         ADVANCE(4);
      DO CASE (LOC(MP+1) & "F");
         /* CASE 0 .EQ. & .NE. */
             IF VAR(MP+1)='.EQ.' THEN EMIT(4000); /* SZA CLA */
                                 ELSE EMIT(4008); /* SNA CLA */
         /* CASE 1 .LT. & .GT. */
             EMIT(4032); /* SMA CLA */
         /* CASE 2 .LE. & .GE. */
             EMIT(4040); /* SPA CLA */  END;
      M,LOC(MP)=GET_TCELL(MP,0);
      EMIT(2688+CB-PAGE_BASE+2); /* JMP */
      EMIT(3713); /* CLA IAC */
      EMIT(1536+M); /* DCA */  END;
/*  <RELATION> ::= .LT.     */  /* STORE A FLAG FOR LOGICAL EXPRESSION */
  LOC(MP)=1;
/*  <RELATION> ::= .LE.     SET REVERSE SUBTRACTION */
  LOC(MP)=2 | SHL(1,8);
/*  <RELATION> ::= .EQ.     */
  LOC(MP)=0;
/*  <RELATION> ::= .NE.     */
```

```
  LOC(MP)=0;
/*  <RELATION> ::= .GT.     SET REVERSE SUBTRACTION */
  LOC(MP)=1 | SHL(1,8);
/*  <RELATION> ::= .GE.     */
  LOC(MP)=2;

/*  <LABELED STATEMENT> ::= <LABEL2> <STATEMENT>     */
  DO;
    LABELED_STATEMENT:
     M=LOC(MP); /* SAVED LABEL */
     IF (LAB(M+127)&"FFFF")=0 THEN DO; LAB(M+127)=LAB(M+127)|CB; RETURN; END;
     ADVANCE(3);
     EMIT(2944+CB-PAGE_BASE+1); /* JMP I */
     CODE(CB)=LAB(M+127) & "FFFF"; /* BACKSTUFF DO STATEMENT */
     CB=CB+1;
     LAB(M+127)=SHL(SHR(LAB(M+127),16),16) | CB;  END;

/*  <LABELED STATEMENT> ::= <LABEL2> CONTINUE     */
     GO TO LABELED_STATEMENT;

/*  <LABEL2> ::= <NUMBER>     */
  DO;LOC(MP),M=FIND_LABEL(FIXV(MP));
     LAB(M+127)=LAB(M+127) | SHL(CB,16);  END;

/*  <ASSIGNMENT STATEMENT> ::= <VARIABLE> <RIGHT PART>     */
  DO;IF LOOKUP(VAR(MP))=0 THEN DO; M=ENTER1(VAR(MP),MP);
               LOC(MP)=SHR(PRT(M)&"FFF00",4)|TYPE;  END;
     IF (LOC(MP)&"1")+(LOC(SP)&"1")=1 THEN
        CALL ERROR('ASSIGNMENT INCOMPATABLE',2);
     IF (LOC(MP)&"1")=1 THEN DO; EMITCK(6,MP); /* FPUT */
                                 EMIT(4096); /* FEXT */
                                 AFLAG=0;     END;
                       ELSE EMITCK(3,MP); /* DCA */  END;

/*  <RIGHT PART> ::= = <EXPRESSION>     */
  DO;LOC(MP)=LOC(MP+1);
     IF (LOC(MP) & "1")=1 THEN
       DO; ADVANCE(6); /* ALLOWS MAX OF TRIPLE ASSIGNMENT */
           AFLAGCK;
           EMITCK(5,MP); /* FGET */  END;
       ELSE EMITCK(1,MP); /* TAD */  END;

/*  <RIGHT PART> ::= = <VARIABLE> <RIGHT PART>     */
  DO;IF LOOKUP(VAR(MP+1))=0 THEN DO; M=ENTER1(VAR(MP+1),MP+1);
               LOC(MP)=SHR(PRT(M)&"FFF00",4)|TYPE;  END;
           ELSE LOC(MP)=LOC(MP+1);
     LOC(MP+1)=LOC(SP);
     IF (LOC(MP)&"1")+(LOC(SP)&"1")=1 THEN
```

```
      CALL ERROR('ASSIGNMENT INCOMPATABLE',2);
   IF (LOC(MP)&"1") =1 THEN EMITCK(6,MP); /* FPUT */
                        ELSE DO; EMITCK(3,MP); /* DCA */
                                 EMITCK(1,MP); /* TAD */  END;   END;

/*  <VARIABLE> ::= <IDENTIFIER>     */
  DO;IF VAR(SP-1)='CALL' THEN DO; /* PARAMETERLESS SUBROUTINE CALL */
      M=FIND_PROC(VAR(MP));
      IF M=0 THEN M=SET_PROC(VAR(MP),2);
      EMIT(2304+SHR(PTABLE(M) & "FFF000",12)); /* JMS I */
      RETURN;  END;
   M=LOOKUP(VAR(MP));
   IF DFLAG=5 THEN RETURN; /* COMMON STATEMENT */
   IF DFLAG=4 THEN DO; /* DATA DECLARATION */
      IF M=0 THEN CALL ENTER1(VAR(MP),MP);
      DIM(DT)=TYPE|(PRT(M) & "FFF00"); /* SAVE TYPE & CORE LOCATION */
      DT=DT+1;
      DIM(0)=DIM(0)+1; /* DATA VARIABLE COUNTER */
      RETURN;    END;
   IF DFLAG=3 THEN DO;
      IF M¬=0 THEN LOC(MP)=(SHL(SHR(SHL(PRT(M),12),20),4)|TYPE)|SHL(PARM,2);
      RETURN;    END;
   IF M=0 THEN M=ENTER(VAR(MP),DFLAG);
         ELSE PRT(M)=SHR(SHL(PRT(M),2),2) | SHL(DFLAG,30);
   IF SFLAG=1 THEN RETURN;
   IF TYPE=1 THEN DO; N=GET_VCELL(3); LOC(MP)=SHL(N,4)|1; END;
             ELSE DO; N=GET_VCELL(1); LOC(MP)=SHL(N,4)|0; END;
   PRT(M)=SHL(N,8) | PRT(M);  END;

/*  <VARIABLE> ::= <SUBSCRIPT HEAD> <EXPRESSION> )      */
  DO;N=(FIXV(MP) & "F") +1; /* COUNTER */
   IF DFLAG=3 THEN
      DO; /* NOT A DECLARATION */
         IF LENGTH(VAR(SP-1))¬=0 THEN
           DO; M=LOOKUP(VAR(SP-1));
               IF M=0 THEN M=ENTER1(VAR(SP-1),SP-1);  END;
         P=SHR(FIXV(MP),8); /* LOCATION */
         IF SHR(FIXV(MP) & "F0",4) <2 THEN
            DO; /* PROCEDURE CALL NOTE CFLAG NOW 1 FOR SUBROUTINE       */
               ADVANCE(3);
               I=GET_VCELL(1);
               CODE(I)=SHR(LOC(MP+1),4);
               EMIT(640+I-PAGE_BASE); /* TAD */
               EMIT(1536+NEXT); /* DCA */
               IF NEXT-1<PARMCELL THEN PARMCELL=NEXT-1;  NEXT=0;
               M=SHR(SHL(PTABLE(P), 4),28); /* # PARAMETERS */
               IF M=0 THEN PTABLE(P)=PTABLE(P) | SHL(N,24);
                      ELSE IF M¬=N THEN
```

```
                    CALL ERROR('PARAMETER COUNT DOES NOT AGREE',2);
             N=SHR(SHL(PTABLE(P), 8),20); /* OCTAL REFERENCE */
             EMIT(2304+N); /* JMS I TO SUBPROGRAM */
             IF CFLAG=0 THEN DO; /* FUNCTION CALL,STORE RETURNED VALUE */
               N=SET(VAR(MP));
               IF N=0 THEN P=GET_TCELL(1);
                      ELSE P=GET_TCELL(3);
               EMIT(1664+P); /* DCA */
               LOC(MP)=SHL(P,4) | N+4;   END;   END;
           ELSE DO; /* COMPUTE SUBSCRIPTS */
                    IF (LOC(MP+1) & "1")=1 THEN CALL ERROR
                      ('SUBSCRIPTING REQUIRES INTEGER EXPRESSION',2);
                    EMITCK(1,MP+1); /* TAD */
                    IF SHR(SHL(FIXV(MP),24),28)=3 THEN EMIT(3616);/* CMA */
                    EMIT(1587); /* DCA 63 */
                    M=52;  DT=DT-1;
                    DO WHILE DT¬=-1;
                      LOC(MP+1)=DIM(DT);
                      EMITCK(1,MP+1); /* TAD */
                      EMIT(1536+M); /* DCA */
                      DT=DT-1;    M=M+1;    END;
                    ADVANCE(4);
                    M=SHR(FIXV(MP),8); /* PRT ADDRESS */
                    N=(SHR(SHL(PRT(M),12),20)); /* ARRAY BASE */
                    IF (PRT(M) & "20000000") > 0 THEN
                      DO; EMIT(512+N); /* TAD */
                         EMIT(1664+CB-PAGE_BASE+2); /* DCA */
                         EMIT(2354); /* JMS I 62 */
                         CB=CB+1;  END;
                      ELSE DO; EMIT(2354);
                               EMIT(N);  END;
                    P=GET_TCELL(MP,0);
                    EMIT(I536+P); /* DCA */
                    P=SHR(SHL(FIXV(MP),24),28);
                    LOC(MP)=LOC(MP)|4+P-2;   END;
          RETURN;  END;
IF DFLAG=4 THEN DO; /* DATA DECLARATION */
   IF FIXV(MP+1)=0 THEN CALL ERROR
     ('DATA VARIABLE SUBSCRIPT MUST BE INTEGER NUMBER',2);
   DIM(DT)=FIXV(MP+1);
   DT=DT+1;  RETURN;  END;
IF (FIXV(MP+1))=0 THEN CALL ERROR('SUBSCRIPTS MUST BE INTEGER NUMBERS',2);
DIM(DT)=FIXV(SP-1); /* INSERT LAST DIMENSION INTO DIM ARRAY */
P=LOOKUP(VAR(MP));
IF P=0 THEN DO; IF DFLAG=2 THEN P=ENTER(VAR(MP),SET(VAR(MP))+2);
                            ELSE P=ENTER(VAR(MP),DFLAG+2);
                TYPE=SHR(PRT(P),30);  END;
    ELSE DO; PRT(P)=PRT(P)+"80000000"; /* DESIG PARAMETER AN ARRAY */
```

```
                    M=1;
                    DO I=0 TO DT;   M=M * DIM(I);   END;
                    SIZE(P-127)=M+DT+2;
                     RETURN;      END;
        IF TYPE=3 THEN DO; DIM(DT+1)=3; LOC(MP)=1; END;
                   ELSE DO; DIM(DT+1)=1; LOC(MP)=0; END;
        DO I=1 TO N-1; /* COMPUTE D SUB I */
           DIM(DT+I+1)=DIM(DT-I+1) * DIM(DT+I);    END;
        M=DT+N+1;
        DIM(M)=DIM(DT+1);
        DO I=0 TO DT;  /* COMPUTE TOTAL CELLS REQUIRED FOR ARRAY */
           DIM(M)=DIM(M) * DIM(I);    END;
        Z=GET_ACELL(DIM(M)+1+N); /* Z IS BASE OF ARRAY BLOCK */
        SIZE(P-127)=DIM(M)+N+1;
        LOC(MP)=LOC(MP) | SHL(Z,4);
        PRT(P)=PRT(P) | SHL(Z,8);
        CODE(Z)=4095-N+1; /* NEG OCTAL NUMBER=NUMBER OF SUBSCRIPTS */
        DO I=1 TO N-1;
           CODE(Z+I)=DIM(DT+I+1);    END;       H=0;
        DO I=1 TO N; /* SUM D SUB I */
           H=H+DIM(DT+I);    END;
        CODE(Z+N)=H;   END;

/*  <SUBSCRIPT HEAD> ::= <IDENTIFIER> (     */
  DO;M=LOOKUP(VAR(MP));
        IF DFLAG=4 THEN DO; /* DATA DECLARATION */
           IF M=0 THEN CALL ERROR('DATA DECLARATIONS REQUIRE ARRAY BE KNOWN',2);
           DIM(DT)=TYPE|(PRT(M) & "FFF00"); /* SAVE TYPE & CORE LOCATION */
           DT=DT+1;
           DIM(0)=DIM(0)+1; /* DATA VARIABLE COUNTER */
           RETURN;   END;
        IF DFLAG=3 THEN DO;  /* NOT A DECLARATION */
           IF M=0 THEN
              DO; /* PROCEDURE CALL */
                  IF NEXT > 0 THEN CALL ERROR
                    ('FUNCTION CALLS WITHIN SUBPROGRAM CALLS NOT ALLOWED',2);
                  M=FIND_PROC(VAR(MP));
                  IF M=0 THEN M=SET_PROC(VAR(MP),CFLAG+1);
                  NEXT=PTABLE(M) & "FFF";
                  IF CFLAG=0 THEN FIXV(MP)=SHL(M,8); /* FUNCTION */
                             ELSE FIXV(MP)="10"|SHL(M,8); /* SUBROUTINE */  END;
             ELSE DO; /* MUST COMPUTE SUBSCRIPT OF ARRAY */
                     IF M=0 THEN CALL ERROR('UNKNOWN ARRAY',2);
                     FIXV(MP)=SHL(M, 8) | SHL(TYPE,4);
                     DT=0;  END;
              RETURN;  END;  /* MUST DIMENSION AN ARRAY */
        DT=0;  FIXV(MP)=0;  END;
```

```
/*  <SUBSCRIPT HEAD> ::= <SUBSCRIPT HEAD> <EXPRESSION> ,     */
  DO;IF DFLAG=3 THEN DO; /* NOT A DECLARATION */
        IF SHR(FIXV(MP) &"F0",4)<2 THEN
           DO; /* A PROCEDURE */
               IF LENGTH(VAR(SP-1))¬=0 THEN
                  DO; M=LOOKUP(VAR(SP-1));
                       IF M=0 THEN M=ENTER1(VAR(SP-1),SP-1);  END;
                FIXV(MP)=FIXV(MP)+1; /* PARAMETER COUNT */
                ADVANCE(3);
                I=GET_VCELL(1);
                CODE(I)=SHR(LOC(MP+1),4);
                EMIT(640+I-PAGE_BASE); /* TAD */
                EMIT(1536+NEXT); /* DCA */
                NEXT=NEXT-1;  END;
            ELSE DO; /* MUST COMPUTE SUBSCRIPT */
                       FIXV(MP)=FIXV(MP) + 1;    /* DIMENSION COUNTER */
                       IF (LOC(MP+1) & "1")=1 THEN CALL ERROR
                         ('SUBSCRIPTING REQURES INTEGER EXPRESSION',2);
                       DIM(DT)=LOC(MP+1);
                       DT=DT+1;  END;
           RETURN;  END;
     IF DFLAG=4 THEN DO; /* DATA DECLARATION */
        IF LENGTH(VAR(MP+1))¬=0 THEN CALL ERROR
          ('DATA VARIABLE SUBSCRIPT MUST BE INTEGER NUMBER',2);
        DIM(DT)=FIXV(MP+1);
        DT=DT+1;
        RETURN;   END;
     IF (FIXV(MP+1))=0 THEN CALL ERROR('SUBSCRIPTS MUST BE INTEGER NUMBERS',2);
     DIM(DT)=FIXV(SP-1);
     DT=DT+1;
     FIXV(MP)=FIXV(MP)+ 1;  END;

/*  <DO STATEMENT> ::= <DO HEAD>     */
  DO;IF (LOC(MP) & "1")=0 THEN STEP=SHL(4,4); /* FIXED POINT ONE */
        ELSE DO; N=STORE_CONSTANT(1,4194304,3); /* FLOATING POINT ONE */
                  STEP=SHL(N,4) | 1;  END;
    DO_HEAD:
     Z=(LOC(MP) & "1") + (STEP & "1") + (DO_UNTIL & "1");
     IF Z=3 THEN Z=1;
      ELSE IF Z¬=0 THEN CALL ERROR('DO EXPRESSIONS ASSIGNMENT INCOMPATABLE',2);
     DO CASE Z;
        /* CASE 0 INTEGER */
        DO; EMITCK(1,MP); /* TAD */
            M=LOC(MP); /* SAVE MP FOR PASSING PARAMETERS */
            LOC(MP)=STEP;
            EMITCK(1,MP); /* TAD */
            LOC(MP)=M;
            EMITCK(3,MP); /* DCA */
```

```
            M=LOC(MP);
            LOC(MP)=DO_UNTIL;
            EMITCK(1,MP); /* TAD */
            EMIT(3616); /* CMA */
            LOC(MP)=M;
            EMITCK(1,MP); /* TAD */   END;
        /* CASE 1 REAL */
        DO; ADVANCE(11);
            AFLAGCK;
            EMITCK(5,MP); /* FGET */
            M=LOC(MP);
            LOC(MP)=STEP;
            EMITCK(1,MP); /* FADD */
            LOC(MP)=M;
            EMITCK(6,MP); /* FPUT */
            M=LOC(MP);
            LOC(MP)=DO_UNTIL;
            EMITCK(2,MP); /* FSUB */
            EMIT(568); /* FADD 70 */
            EMIT(0000); /* FEXT */
            LOC(MP)=M;
            EMIT(549); /* TAD 45 */  END;  END;
     ADVANCE(3);
     EMIT(4032); /* SMA CLA */
     P=SETLAB(SAVE_LABEL_ADDRESS,1);
     EMIT(2944+P); /* JMP I */
     CODE(SAVE_FIRST)=CB;  END;

/*  <DO STATEMENT> ::= <DO HEAD> , <EXPRESSION>     */
  DO;STEP=LOC(SP);  GO TO DO_HEAD;  END;

/* .<DO HEAD> ::= <DO VARIABLE> , <EXPRESSION>     */
     DO_UNTIL=LOC(SP);

/*  <DO VARIABLE> ::= <DO LABEL> <VARIABLE> = <EXPRESSION>     */
  DO;N=LOOKUP(VAR(MP+1));
     IF N=0 THEN CALL ENTER1(VAR(MP+1),MP+1);
     IF (LOC(MP+1) & "1") + (LOC(SP) & "1")=1 THEN
        CALL ERROR('DO VARIABLE ASSIGNMENT INCOMPATABLE',2);
     DO CASE (LOC(SP) & "1");
        /* CASE 0 INTEGER ASSIGNMENT */
        DO; EMITCK(1,SP); /* TAD */
            EMITCK(3,MP+1); /* DCA */  END;
        /* CASE 1 REAL ASSIGNMENT */
        DO; ADVANCE(6);
            EMIT(2311); /* JMS I 7 */
            EMITCK(5,SP); /* FGET */
            EMITCK(6,MP+1); /* FPUT */
```

```
            EMIT(0000); /* FEXT */  END;  END;
      ADVANCE(2);
      EMIT(2944+CB-PAGE_BASE+1); /* JMP TO FIRST STATEMENT */
      SAVE_FIRST=CB; CB=CB+1; /* STUFF WITH ADDRESS OF FIRST STATEMENT */
      IF LAB(LOC(MP)+127)¬=0 THEN DO;  CALL ERROR(' ',2);
         OUTPUT='NESTED DO LOOPS MUST NOT END ON SAME LABELED STATEMENT';
         OUTPUT=' --OR- DUPLICATE LABEL'; OUTPUT=' ';  END;
      LAB(LOC(MP)+127)=CB; /* RETURN FOR INCREMENT */
      LOC(MP)=LOC(MP+1); /* SAVE THE VARIABLE */  END;

/*  <DO LABEL> ::= DO <NUMBER>    */
   LOC(MP),SAVE_LABEL_ADDRESS=FIND_LABEL(FIXV(SP));

/*  <GO STATEMENT> ::= <GOTO> <NUMBER>    */
   DO;M=FIND_LABEL(FIXV(SP));
      P=SETLAB(M,0);
      EMIT(2944+P); /* JMP I */ END;

/*  <GO STATEMENT> ::= <GO TRANSFER> <END GO> <VARIABLE>    */
   DO;IF (LOC(SP) & "1")=1 THEN CALL ERROR('VARIABLE MUST BE INTEGER TYPE',2);
      EMITCK(1,SP); /* TAD */
      ADVANCE(DT+3);
      EMIT(640+CB-PAGE_BASE+3); /* TAD */
      EMIT(1664+CB-PAGE_BASE+1); /* DCA */
      CB=CB+1;
      EMIT(2944+CB-PAGE_BASE); /* JMP - LABELS FOLLOW */
      DO I=0 TO DT-1;
         CODE(CB)=SHL(DIM(I),16);  CB=CB+1;  END;  END;

/*  <GOTO> ::= GO TO    */
   ;

/*  <GOTO> ::= GOTO    */
   ;

/*  <GO TRANSFER> ::= <GOTO> <PAREN> <NUMBER>    */
   DO;DT=0;  DIM(DT)=FIND_LABEL(FIXV(SP));  DT=DT+1;  END;

/*  <GO TRANSFER> ::= <GO TRANSFER> <CCMMA> <NUMBER>    */
   DO;DIM(DT)=FIND_LABEL(FIXV(SP));  DT=DT+1;  END;

/*  <PAREN> ::= (    */
   ;

/*  <COMMA> ::= ,    */
   ;

/*  <END GO> ::= ) ,    */
```

```
   ;
/*  <DECLARATION LIST> ::= <DECLARATION> ;     */
   DFLAG=3;

/*  <DECLARATION LIST> ::= <DECLARATION LIST> <DECLARATION> ;     */
   DFLAG=3;

/*  <DECLARATION> ::= <DECLARATION TYPE> <VARIABLE>     */
   IF DFLAG=5 THEN CALL COMMON_CHECK(SP);

/*  <DECLARATION> ::= <DECLARATION TYPE> <VARIABLE LIST> <VARIABLE>     */
   IF DFLAG=5 THEN CALL COMMON_CHECK(SP);

/*  <DECLARATION> ::= <DATA DECLARATION> <NUMBER> /     */
   DO;CALL INSERT_DATA;
      IF (DIM(0) & "FF")¬=SHR(DIM(0),8) THEN CALL ERROR
         ('NUMBER OF VARIABLES AND DATA DO NOT MATCH',2);   END;

/*  <DECLARATION TYPE> ::= DIMENSION     */
   DFLAG=2;

/*  <DECLARATION TYPE> ::= INTEGER     */
   DFLAG=0;

/*  <DECLARATION TYPE> ::= REAL     */
   DFLAG=1;

/*  <DECLARATION TYPE> ::= COMMON     */
   DFLAG=5;

/*  <VARIABLE LIST> ::= <VARIABLE> ,     */
   IF DFLAG=5 THEN CALL COMMON_CHECK(SP-1);

/*  <VARIABLE LIST> ::= <VARIABLE LIST> <VARIABLE> ,     */
   IF DFLAG=5 THEN CALL COMMON_CHECK(SP-1);

/*  <DATA DECLARATION> ::= <DATA HEAD> /     */
   DT=1;

/*  <DATA DECLARATION> ::= <DATA DECLARATION> <NUMBER> ,     */
   CALL INSERT_DATA;

/*  <DATA HEAD> ::= <DATA> <VARIABLE>     */
   ;

/*  <DATA HEAD> ::= <DATA> <VARIABLE LIST> <VARIABLE>     */
   ;
```

```
/*  <DATA> ::= DATA    */
  DO;DT=1;
     DIM(0)=0; /* VARIABLE COUNTER */
     DFLAG=4;   END;

/*  <PROCEDURE BLOCK> ::= <PROCEDURE HEADING>  */
  DO;
    PROCEDURE_HEADING:
     P=SHR(FIXV(MP),8); /* PTABLE ENTRY */
     P=SHR(PTABLE(P) & "FFF000",12); /* OCTAL REFERENCE ON PAGE ZERO */
     CODE(P)=ENTRY & "FFF";  END;

/*  <PROCEDURE BLOCK> ::= <PROCEDURE HEADING> <DECLARATION LIST>  */
  GO TO PROCEDURE_HEADING;

/*  <PROCEDURE HEADING> ::= <PARAMLESS PROCEDURE>    */
   ;

/*  <PROCEDURE HEADING> ::= <PROCEDURE & PARAMETERS>    */
   ;

/*  <PARAMLESS PROCEDURE> ::= SUBROUTINE <IDENTIFIER> ;    */
  DO;ENTRY=STORE_CODE(0000);
     P=FIND_PROC(VAR(SP-1));  SFLAG=2;
     IF P=0 THEN P=SET_PROC(VAR(SP-1),2);
        ELSE DO; IF SHR(SHL(PTABLE(M),4),28) ¬=0 THEN
                    CALL ERROR('#PARAMETERS DOES NOT AGREE WITH PRIOR USE',2);
                 IF SHR(PTABLE(P),29) ¬= 2 THEN
                 CALL ERROR('PROCEDURE USED AS BOTH FUNCTION & SUBROUTINE',2);
              END;
   . PTABLE(P)=PTABLE(P)+ "10000000"; /* INDICATE PROCEDURE KNOWN */
     FIXV(MP)=SHL(P,8);  END;

/*  <PROCEDURE & PARAMETERS> ::= <PROCEDURE HEAD> <IDENTIFIER> ) ;    */
  DO;M=ENTER(VAR(SP-2),SET(VAR(SP-2)));
     PRT(M)=PRT(M) | SHL(1,29);
     PRT(M)=PRT(M)|SHL(NEXT,8);
     IF NEXT-1 < PARMCELL THEN PARMCELL=NEXT-1;  NEXT=0;
     P=SHR(FIXV(MP),8); /* LOCATION OF PROCEDURE NAME */
     FIXV(MP)=FIXV(MP)+1;
     N=FIXV(MP) & "F";
     PTABLE(P)=PTABLE(P)+ "10000000"; /* INDICATE PROCEDURE KNOWN */
     IF (PTABLE(P) & "F000000")=0 THEN PTABLE(P)=PTABLE(P)|SHL(N,24);
       ELSE IF SHR(SHL(PTABLE(P),4),28) ¬=  (FIXV(MP) & "F") THEN
          CALL ERROR('PARAMETER COUNT DOES NOT AGREE WITH PRIOR USE',2); END;

/*  <PROCEDURE HEAD> ::= <PROCEDURE TYPE>    */
```

```
;

/*  <PROCEDURE HEAD> ::= <PROCEDURE HEAD> <IDENTIFIER> ,      */
  DO;M=ENTER(VAR(SP-1),SET(VAR(SP-1)));
     PRT(M)=PRT(M) | SHL(1,29);
     FIXV(MP)=FIXV(MP)+1;
     PRT(M)=PRT(M)| SHL(NEXT,8);
     NEXT=NEXT-1;   END;
/*  <PROCEDURE TYPE> ::= FUNCTION <IDENTIFIER> (     */
  DO;ENTRY=STORE_CODE(0000);   SFLAG=1;
     P=FIND_PROC(VAR(SP-1));
     IF P=0 THEN P=SET_PROC( VAR(SP-1) ,1);
       ELSE IF SHR(PTABLE(P),29) ¬=1 THEN
           CALL ERROR('PROCEDURE USED AS BOTH FUNCTION & SUBROUTINE',2);
     NEXT=PTABLE(P) & "FFF";
     FIXV(MP)=SHL(P,8) | SHL(1,4);
     M=ENTER1(VAR(SP-1),SP-1);
       /* SAVE OCTAL LOCATION OF VARIABLE FOR RETURN */
     ENTRY=ENTRY | SHL(PRT(M) & "FFF00",8);   END;

/*  <PROCEDURE TYPE> ::= SUBROUTINE <IDENTIFIER> (     */
  DO;ENTRY=STORE_CODE(0000);   SFLAG=2;
     P=FIND_PROC(VAR(SP-1));
     IF P=0 THEN P=SET_PROC( VAR(SP-1) ,2);
       ELSE IF SHR(PTABLE(P),29) ¬=2 THEN
           CALL ERROR('PROCEDURE USED AS BOTH FUNCTION & SUBROUTINE',2);
     NEXT=PTABLE(P) & "FFF";
     FIXV(MP)=SHL(P,8) | SHL(1,4);   END;

/*  <SUBROUTINE CALL> ::= <CALL> <VARIABLE>     */
  CFLAG=0;

/*  <CALL> ::= CALL     */
  CFLAG=1;

/*  <READ STATEMENT> ::= <READ HEAD> <VARIABLE> )     */
  DO;
  READ:
     M=LOOKUP(VAR(SP-1));
     IF M=0 THEN M=ENTER1(VAR(SP-1),SP-1);
     EMIT(2310); /* JMS I 6 */
     AFLAGCK;
     IF (LOC(SP-1) &"1")=1 THEN DO; EMITCK(6,SP-1); /* FPUT */
                                     EMIT(4096); /* FEXT */  AFLAG=0;
      /* CONVERT REAL TO INTEGER */  RETURN;   END;
     EMIT(0000); /* FEXT */    AFLAG=0;
     EMIT(2335); /* JMS I 37 */
     EMITCK(3,SP-1); /* DCA */  END;
```

```
/*  <READ HEAD> ::= READ (     */
   ;

/*  <READ HEAD> ::= <READ HEAD> <VARIABLE> ,     */
   GO TO READ;

/*  <WRITE STATEMENT> ::= <WRITE HEAD> <EXPRESSION> )     */
   DO;
      WRITE_EXPRESSION:
       IF (LOC(SP-1) & "1")=1 THEN DO; AFLAGCK;
                                       EMITCK(5,SP-1); /* FGET */
                                       EMIT(0000); /* FEXT */  AFLAG=0;  END;
            ELSE DO; EMITCK(1,SP-1); /* TAD */
                     EMIT(2334); /* JMS I 36 */  END;
       EMIT(2309); /* JMS I 5 */  END;

/*  <WRITE STATEMENT> ::= <WRITE HEAD> <STRING> )     */
   CALL EMIT_STRING(VAR(SP-1));

/*  <WRITE STATEMENT> ::= <WRITE HEAD> <TAB EXPRESSION> )     */
   ;

/*  <WRITE HEAD> ::= WRITE (     */
   DO;EMITCAR(141); /* RETURN */
      EMITCAR(138); /* LINE FEED */  END;

/*  <WRITE HEAD> ::= WRITEON (     */
   ;

/*  <WRITE HEAD> ::= <WRITE HEAD> <EXPRESSION> ,     */
   GO TO WRITE_EXPRESSION;

/*  <WRITE HEAD> ::= <WRITE HEAD> <STRING> ,     */
   CALL EMIT_STRING(VAR(SP-1));

/*  <WRITE HEAD> ::= <WRITE HEAD> <TAB EXPRESSION> ,     */
   ;

/*  <TAB EXPRESSION> ::= TAB <EXPRESSION>     */
   DO;ADVANCE(2);
      EMIT(2332); /* JMS I 34 */
      EMIT(4096-FIXV(SP));  END;  END;
END SYNTHESIZE;

  /*              SYNTACTIC PARSING FUNCTIONS                          */
```

```
RIGHT_CONFLICT:
   PROCEDURE (LEFT) BIT(1);
      DECLARE LEFT FIXED;
      /*  THIS PROCEDURE IS TRUE IF TOKEN IS ¬ A LEGAL RIGHT CONTEXT OF LEFT*/
      RETURN ("C0" & SHL(BYTE(C1(LEFT), SHR(TOKEN,2)), SHL(TOKEN,1)
         & "06")) = 0;
   END RIGHT_CONFLICT;

RECOVER:
   PROCEDURE;
      /* IF THIS IS THE SECOND SUCCESSIVE CALL TO RECOVER, DISCARD ONE SYMBOL */
      IF ¬ FAILSOFT THEN CALL SCAN;
      FAILSOFT = FALSE;
      DO WHILE ¬ STOPIT(TOKEN);
         CALL SCAN;  /* TO FIND SOMETHING SOLID IN THE TEXT  */  END;
      DO WHILE RIGHT_CONFLICT (PARSE_STACK(SP));
         IF SP > 2 THEN SP = SP - 1;  /* AND IN THE STACK  */
         ELSE CALL SCAN;  /* BUT DON'T GO TOO FAR  */  END;
      OUTPUT = 'RESUME:' || SUBSTR(POINTER, TEXT_LIMIT-CP+MARGIN_CHOP+7);
   END RECOVER;

STACKING:
   PROCEDURE BIT(1);  /* STACKING DECISION FUNCTION */
      CALLCOUNT(1) = CALLCOUNT(1) + 1;
      DO FOREVER;    /* UNTIL RETURN  */
         DO CASE SHR(BYTE(C1(PARSE_STACK(SP)),SHR(TOKEN,2)),SHL(3-TOKEN,1)&6)&3;

            /*  CASE 0  */
            DO;    /* ILLEGAL SYMBOL PAIR  */
               CALL ERROR('ILLEGAL SYMBOL PAIR: ' || V(PARSE_STACK(SP)) || X1 ||
                  V(TOKEN), 1);
               CALL STACK_DUMP;
               CALL RECOVER;  END;

            /*  CASE 1  */
            RETURN TRUE;      /*  STACK TOKEN  */

            /*  CASE 2  */
            RETURN FALSE;     /* DON'T STACK IT YET  */

            /*  CASE 3  */
            DO;       /* MUST CHECK TRIPLES  */
               J = SHL(PARSE_STACK(SP-1), 16) + SHL(PARSE_STACK(SP), 8) + TOKEN;
               I = -1;  K = NC1TRIPLES + 1;  /* BINARY SEARCH OF TRIPLES  */
               DO WHILE I + 1 < K;
                  L = SHR(I+K, 1);
                  IF C1TRIPLES(L) > J THEN K = L;
                  ELSE IF C1TRIPLES(L) < J THEN I = L;
```

```
                 ELSE RETURN TRUE;  /* IT IS A VALID TRIPLE  */  END;
               RETURN FALSE;  END;
           END;     /* OF DO CASE  */
         END;   /*  OF DO FOREVER */
      END STACKING;

   PR_OK:
      PROCEDURE(PRD) BIT(1);
         /* DECISION PROCEDURE FOR CONTEXT CHECK OF EQUAL OR IMBEDDED RIGHT PARTS*/
         DECLARE (H, I, J, PRD) FIXED;
         DO CASE CONTEXT_CASE(PRD);
            /*  CASE 0 -- NO CHECK REQUIRED  */
            RETURN TRUE;

            /*  CASE 1 -- RIGHT CONTEXT CHECK  */
            RETURN ¬ RIGHT_CONFLICT (HDTB(PRD));

            /*  CASE 2 -- LEFT CONTEXT CHECK  */
            DO;H = HDTB(PRD) - NT;
               I = PARSE_STACK(SP - PRLENGTH(PRD));
               DO J = LEFT_INDEX(H-1) TO LEFT_INDEX(H) - 1;
                  IF LEFT_CONTEXT(J) = I THEN RETURN TRUE;  END;
               RETURN FALSE;  END;

            /*  CASE 3 -- CHECK TRIPLES  */
            DO;H = HDTB(PRD) - NT;
               I = SHL(PARSE_STACK(SP - PRLENGTH(PRD)), 8) + TOKEN;
               DO J = TRIPLE_INDEX(H-1) TO TRIPLE_INDEX(H) - 1;
                  IF CONTEXT_TRIPLE(J) = I THEN RETURN TRUE;  END;
               RETURN FALSE;  END;
         END;  /* OF DO CASE  */
      END PR_OK;

    /*                        ANALYSIS ALGORITHM                              */

   REDUCE:
      PROCEDURE;
         DECLARE (I, J, PRD) FIXED;
         /* PACK STACK TOP INTO ONE WORD */
         DO I = SP - 4 TO SP - 1;
            J = SHL(J, 8) + PARSE_STACK(I);  END;
         DO PRD = PR_INDEX(PARSE_STACK(SP)-1) TO PR_INDEX(PARSE_STACK(SP)) - 1;
            IF (PRMASK(PRLENGTH(PRD)) & J) = PRTB(PRD) THEN
               IF PR_OK(PRD) THEN
               DO;  /* AN ALLOWED REDUCTION */
                  MP = SP - PRLENGTH(PRD) + 1; MPP1 = MP + 1;
        IF CONTROL(BYTE('P')) THEN DO;
           S='                  ' || V(HDTB(PRD)) || ' ::= ';
```

```
          DO I=MP TO SP;  S=S || V(PARSE_STACK(I)) || ' ';  END;
          OUTPUT=S;  END;
               CALL SYNTHESIZE(PRDTB(PRD));
               SP = MP;
               PARSE_STACK(SP) = HDTB(PRD);
               RETURN;  END;  END;
      /* LOOK UP HAS FAILED, ERROR CONDITION */
      CALL ERROR('NO PRODUCTION IS APPLICABLE',1);
      CALL STACK_DUMP;
      FAILSOFT = FALSE;
      CALL RECOVER;
   END REDUCE;

COMPILATION_LOOP:
   PROCEDURE;
      COMPILING = TRUE;
      DO WHILE COMPILING;     /* ONCE AROUND FOR EACH PRODUCTION (REDUCTION)  */
         DO WHILE STACKING;
            SP = SP + 1;
            IF SP = STACKSIZE THEN
               DO;CALL ERROR ('STACK OVERFLOW *** CHECKING ABORTED ***', 2);
                  RETURN;   /* THUS ABORTING CHECKING */  END;
            PARSE_STACK(SP) = TOKEN;
            VAR(SP) = BCD;
            IF NFLAG=1 THEN DO; FIXV(SP)=HOLD1; /* REAL NUMBER */
                                FIXM(SP)=HOLD2|SHL(1,30);  END;
                       ELSE DO; FIXV(SP)=NUMBER_VALUE; /* INTEGER NUMBER */
                                FIXM(SP)=0;  END;  NFLAG=0;
            CALL SCAN;  END;
         CALL REDUCE;
      END;     /* OF DO WHILE COMPILING  */
   END COMPILATION_LOOP;


PRINT_SUMMARY:
   PROCEDURE;
      DECLARE I FIXED;
      CALL PRINT_DATE_AND_TIME ('END OF CHECKING ', DATE, TIME);
      OUTPUT = '';
      OUTPUT = CARD_COUNT || ' CARDS WERE CHECKED.';
      IF ERROR_COUNT = 0 THEN OUTPUT = 'NO ERRORS WERE DETECTED.';
      ELSE IF ERROR_COUNT > 1 THEN
         OUTPUT = ERROR_COUNT || ' ERRORS (' || SEVERE_ERRORS
            || ' SEVERE) WERE DETECTED.';
      ELSE IF SEVERE_ERRORS = 1 THEN OUTPUT = 'ONE SEVERE ERROR WAS DETECTED.';
         ELSE OUTPUT = 'ONE ERROR WAS DETECTED.';
      IF PREVIOUS_ERROR > 0 THEN
         OUTPUT = 'THE LAST DETECTED ERROR WAS ON LINE ' || PREVIOUS_ERROR
```

```
            || PERIOD;
        IF CONTROL(BYTE('D')) THEN CALL DUMPIT;
        DOUBLE_SPACE;
        CLOCK(3) = TIME;
        DO I = 1 TO 3;     /* WATCH OUT FOR MIDNIGHT */
           IF CLOCK(I) < CLOCK(I-1) THEN CLOCK(I) = CLOCK(I) +  8640000;  END;
        CALL PRINT_TIME ('TOTAL TIME IN CHECKER     ', CLOCK(3) - CLOCK(0));
        CALL PRINT_TIME ('SET UP TIME               ', CLOCK(1) - CLOCK(0));
        CALL PRINT_TIME ('ACTUAL CHECKING TIME      ', CLOCK(2) - CLOCK(1));
        CALL PRINT_TIME ('CLEAN-UP TIME AT END      ', CLOCK(3) - CLOCK(2));
        IF CLOCK(2) > CLOCK(1) THEN    /* WATCH OUT FOR CLOCK BEING OFF */
        OUTPUT = 'CHECKING RATE: ' || 6000*CARD_COUNT/(CLOCK(2)-CLOCK(1))
           || ' CARDS PER MINUTE.';
     END PRINT_SUMMARY;

  MAIN_PROCEDURE:
     PROCEDURE;
        CLOCK(0) = TIME;  /* KEEP TRACK OF TIME IN EXECUTION */
        CALL INITIALIZATION;
        CLOCK(1) = TIME;
        CALL COMPILATION_LOOP;
        CLOCK(2) = TIME;
        /* CLOCK(3) GETS SET IN PRINT_SUMMARY */
        CALL PRINT_SUMMARY;
     END MAIN_PROCEDURE;

  CALL MAIN_PROCEDURE;
  RETURN SEVERE_ERRORS;

  EOF EOF EOF
```

APPENDIX G

FORTRAN/8 LISTING CONTROLS

The following is a listing of control toggles which allow the user to print the code array and FORTRAN/8 tables during the listing.

Each command must appear on a separate card. A dollar sign ($) must be punched in column one of the card and the control character must follow in column two. With the exception of control toggle L, all toggles are initially off. The first appearance of a control card complements the toggle (if off then it is turned on). Succeeding appearances of the same control card again complements the toggle.

Character	Action
C	causes the code generated by each source deck statement to follow a listing of that statement
L	causes the source deck statement to be listed along with the card count
M	causes the source deck card to be listed without the card count
P	causes the BNF productions to be listed while the source deck statement is being parsed. It should be noted that the statement will follow the productions.
R	upon completion of code generation the PDP-8 memory map from 0_8 to the page (current page) on which code generation ceased along with all addresses not equal to zero from the current page to address 5473_8 will be listed

Character	Action
S	causes the PRT to be listed after each program block
T	causes the PTABLE to be printed at the end of compilation

APPENDIX H

PDP-8 INSTRUCTION SET

Mnemonic	Code	Operation
		BASIC INSTRUCTIONS
AND	0000	logical AND
TAD	1000	2's complement add
ISZ	2000	increment and skip if zero
DCA	3000	deposit and clear AC
JMS	4000	jump to subroutine
JMP	5000	jump
IOT	6000	in/out transfer
OPR	7000	operate
		GROUP 1 OPERATE MICROINSTRUCTIONS
NOP	7000	no operation
CLA	7200	clear AC
CLL	7100	clear link
CMA	7040	complement AC
CML	7020	complement link
RAR	7010	rotate AC and link right one
RAL	7004	rotate AC and link left one
RTR	7012	rotate AC and link right two
RTL	7006	rotate AC and link left two
IAC	7001	increment AC
		GROUP 2 OPERATE MICROINSTRUCTIONS
SMA	7500	skip on minus AC
SZA	7440	skip on zero AC
SPA	7510	skip on plus AC
SNA	7450	skip on non-zero AC
SNL	7420	skip on non-zero link
SZL	7430	skip on zero link
SKP	7410	skip unconditionally
OSR	7404	inclusive OR, switch register with AC
HLT	7402	halts the program
CLA	7600	clear AC

Mnemonic	Code	Operation
		COMBINED OPERATE MICROINSTRUCTIONS
CIA	7041	complement and increment AC
LAS	7604	load AC with switch register
STL	7120	set link (to 1)
GLK	7204	get link (put link in AC bit 11)
CLA CLL	7300	clear AC and link
CLA IAC	7201	set AC = 1
CLA CMA	7240	set AC = -1
CLL RAR	7110	shift positive number one right
CLL RAL	7104	shift positive number one left
CLL RTL	7106	clear link, rotate 2 left
CLL RTR	7112	clear link, rotate 2 right
SZA CLA	7640	skip if AC = 0, then clear AC
SZA SNL	7460	skip if AC = 0 or link = 1, or both
SNA CLA	7650	skip if AC ≠ 0, then clear AC
SMA CLA	7700	skip if AC < 0, then clear AC
SMA SZA	7540	skip if AC < = 0
SMA SNL	7520	skip if AC < 0 or link is 1, or both
SPA SNA	7550	skip if AC > 0
SPA SZL	7530	skip if AC > = 0, and if link is 0
SPA CLA	7710	skip if AC > = 0, then clear AC
SNA SZL	7470	skip if AC ≠ 0 and link = 0
		M Q MICROINSTRUCTIONS
NOP	7401	no operation
CLA	7601	clear AC
MQL	7421	load MQ from AC then clear AC
MQA	7501	inclusive OR the MQ with the AC
CAM	7621	clear AC and MQ
SWP	7521	swap AC and MQ
ACL	7701	load MQ into AC
CLA,SWP	7721	load AC from MQ then clear MQ

Mnemonic	Code	Operation
		TELETYPE KEYBOARD/READER
KCF	6030	clear keyboard/reader flag, do not start reader
KSF	6031	skip if keyboard/reader flag = 1
KCC	6032	clear AC and keyboard/reader flag, set reader run
KRS	6034	read keyboard/reader buffer static
KIE	6035	AC 11 to keyboard/reader interrupt enable F.F.
KRB	6036	clear AC, read keyboard buffer, clear keyboard flags
		TELETYPE TELEPRINTER/PUNCH
SPF	6040	set teleprinter/punch flag
TSF	6041	skip if teleprinter/punch flag = 1
TCF	6042	clear teleprinter/punch flag
TPC	6044	load teleprinter/punch buffer select and print
SPI	6045	skip if teletype interrupt
TLS	6046	load teleprinter/punch buffer, select and print and clear teleprinter/punch flag
		FLOATING POINT INSTRUCTIONS
FADD	1000	add to floating point AC
FSUB	2000	subtract from floating point AC
FMPY	3000	multiply floating point AC by
FDIV	4000	divide floating point AC by
FGET	5000	load floating point AC by
FPUT	6000	store floating point AC by
FNOR	7000	normalize floating point AC by
FEXT	0000	floating point exit
SQR	0001	floating point square
SQRT	0002	floating point square root
		PSEUDO INSTRUCTION
WEXT	0000	WRITE_STRING subroutine exit

APPENDIX I

PDP-8 MACHINE LANGUAGE SUBPROGRAMS

FLOAT SUBPROGRAM

Address	Code	Label	Mnemonic Description
5435	0000	ENTRY,	
5436	7100		CLL
5437	7500		SMA
5440	5243		JMP. +3
5441	7120		STL
5442	0362		AND
5443	3046		DCA 46
5444	7300		CLA CLL
5445	3044		DCA 44
5446	7204		GLK
5447	7650		SNA CLA
5450	5253		JMP. +3
5451	1362		TAD
5452	7040		CMA
5453	7421		MQL
5454	1046		TAD 46
5455	7450		SNA
5456	5262		JMP. +4
5457	2044		ISZ 44
5460	7010		RAR
5461	5255		JMP. -4
5462	1046		TAD 46
5463	7510		SPA
5464	5267		JMP. +3
5465	7004		RAL
5466	5263		JMP. -3
5467	7010		RAR
5470	7501		MQA
5471	3045		DCA 45
5472	3046		DCA 46
5473	5235		JMP I ENTRY

TAB SUBPROGRAM

Address	Code	Label	Mnemonic	Description
5474	0000	ENTRY,		
5475	1674		TAD I ENTRY	
5476	3313		DCA A	
5477	2274		ISZ ENTRY	
5500	4435		JMS I 35	
5501	0215			/return
5502	0000		WEXT	/exit
5503	1313		TAD A	
5504	7700		SMA CLA	
5505	5674		JMP I ENTRY	
5506	4435		JMS I 35	
5507	0240			/space
5510	0000		WEXT	/exit
5511	2313		ISZ A	
5512	5305		JMP. -7	
5513	0000	A,		

WRITE_STRING SUBPROGRAM

Address	Code	Label	Mnemonic	Description
5514	0000	ENTRY,		
5515	7300		CLA CLL	
5516	6046		TLS	
5517	1714		TAD I ENTRY	
5520	2314		ISZ ENTRY	
5521	7450		SNA	
5522	5714		JMP I ENTRY	
5523	6041		TSF	
5524	5323		JMP. -1	
5525	6046		TLS	
5526	7300		CLA CLL	
5527	5317		JMP. -8	

INTEGER_WRITE SUBPROGRAM

Address	Code	Label	Mnemonic Description
5530	0000	ENTRY,	
5531	3045		DCA 45
5532	1045		TAD 45
5533	7700		SMA CLA
5534	5342		JMP. +6
5535	1045		TAD 45
5536	7040		CMA
5537	1004		TAD 4
5540	3045		DCA 45
5541	1362		TAD A
5542	7421		MQL
5543	3046		DCA 46
5544	3044		DCA 44
5545	1045		TAD 45
5546	7010		RAR
5547	2044		ISZ 44
5550	7440		SZA
5551	5346		JMP. -3
5552	1045		TAD 45
5553	7004		RAL
5554	7500		SMA
5555	5353		JMP. -2
5556	7010		RAR
5557	7501		MQA
5560	3045		DCA 45
5561	5730		JMP I ENTRY
5562	4000	A,	/mask

INTEGER_READ SUBPROGRAM

Address	Code	Label	Mnemonic Description
5563	0000	ENTRY,	
5564	1044		TAD 44
5565	1377		TAD A
5566	7700		SMA CLA
5567	5375		JMP. +6
5570	1045		TAD 45
5571	7110		CLL RAR
5572	3045		DCA 45
5573	2044		ISZ 44
5574	5364		JMP. -8
5575	1045		TAD 45
5576	5763		JMP I ENTRY
5577	7765	A,	$/-11_8$

ARRAY_SUBSCRIPTOR SUBPROGRAM

Address	Code	Label	Mnemonic Description
7600	0000	ENTRY,	
7601	1600		TAD I ENTRY
7602	3357		DCA BASE
7603	2200		ISZ ENTRY
7604	1757		TAD I BASE
7605	3360		DCA DIM
7606	2357		ISZ BASE
7607	1063		TAD RN
7610	7500		SMA
7611	5217		JMP
7612	7040		CMA
7613	3356		DCA CALC
7614	1356		TAD CALC
7615	1356		TAD CALC
7616	1356		TAD CALC
7617	3356		DCA CALC
7620	2360		ISZ DIM
7621	5223		JMP
7622	5241		JMP .
7623	2360		ISZ DIM
7624	1757		TAD I BASE
7625	3361		DCA DI
7626	2357		ISZ BASE

ARRAY_SUBSCRIPTOR SUBPROGRAM (Continued)

Address	Code	Label	Mnemonic Description
7627	1063		TAD I
7630	7040		CMA
7631	1004		TAD
7632	3362		DCA RI
7633	1362		TAD RI
7634	2362		ISZ RI
7635	5233		JMP
7636	1356		TAD CALC
7637	3356		DCA CALC
7640	5220		JMP
7641	1207		TAD
7642	3327		DCA
7643	1757		TAD I BASE
7644	7040		CMA
7645	1003		TAD 3
7646	1357		TAD BASE
7647	1356		TAD CALC
7650	5200		JMP I ENTRY
7651	0000		NOP
7756	0000	CALC,	
7757	0000	BASE,	
7760	0000	DIM,	
7761	0000	DI,	
7762	0000	RI,	

MULTIPLY SUBPROGRAM

Address	Code	Label	Mnemonic Description
7652	0000	ENTRY,	
7653	7300		CLA CLL
7654	1652		TAD I ENTRY /Multipler Address
7655	3356		DCA A
7656	1756		TAD I A
7657	3356		DCA A
7660	2252		ISZ ENTRY
7661	1652		TAD I ENTRY /Multiplicand Address
7662	3357		DCA B
7663	1757		TAD I B
7664	7040		CMA

MULTIPLY SUBPROGRAM (Continued)

Address	Code	Label	Mnemonic Description
7665	3357		DCA B
7666	2252		ISZ ENTRY
7667	2357		ISZ B
7670	5272		JMP. +2
7671	5652		JMP I ENTRY
7672	1356		TAD A
7673	5267		JMP. -4
7756	0000	A,	
7757	0000	B,	

DIVIDE SUBPROGRAM

Address	Code	Label	Mnemonic Description
7674	0000	ENTRY,	
7675	7300		CLA CLL
7676	1674		TAD I ENTRY /Dividend Address
7677	3356		DCA A
7700	1756		TAD I A
7701	3356		DCA A
7702	2274		ISZ ENTRY
7703	1674		TAD I ENTRY /Divisor Address
7704	2274		ISZ ENTRY
7705	3357		DCA B
7706	1757		TAD I B
7707	7040		CMA
7710	1004		TAD 4
7711	7440		SZA
7712	5314		JMP. +2
7713	7402		HLT /Divide by Zero?
7714	3357		DCA B
7715	3360		DCA C
7716	1356		TAD A
7717	1357		TAD B
7720	2360		ISZ C
7721	7540		SMA SZA
7722	5317		JMP. -3
7723	7500		SMA
7724	5326		JMP. +2
7725	1002		TAD 2

DIVIDE SUBPROGRAM (Continued)

Address	Code	Label	Mnemonic Description
7726	1360		TAD C
7727	5674		JMP I ENTRY
7756	0000	A,	
7757	0000	B,	
7760	0000	C,	

EXPONENTIATION SUBPROGRAM

Address	Code	Label	Mnemonic Description
7730	0000	ENTRY,	
7731	7300		CLA CLL
7732	1730		TAD I ENTRY
7733	3356		DCA A
7734	1756		TAD I A
7735	7040		CMA
7736	1004		TAD 4
7737	3356		TAD A
7740	2330		ISZ ENTRY
7741	1730		TAD I ENTRY
7742	3357		DCA B
7743	2330		ISZ ENTRY
7744	4407		JMS INTREPTER /Floating Point Package
7745	5757		FGET I B
7746	6357		FPUT B
7747	0000		FEXT
7750	4407		JMS INTREPTER
7751	3357		FMPY B
7752	0000		FEXT
7753	2356		ISZ A
7754	5350		JMP. -4
7755	5730		JMP I ENTRY
7756	0000	A,	
7757	0000	B,	
7760	0000		
7761	0000		

LIST OF REFERENCES

1. McKeeman, W.M., Horning, J.J., Wortman, D.B., A Compiler Generator, Prentice-Hall, Inc., 1970.

2. Naur, Peter, et al, "Revised Report on the Algorithmic Language, ALGOL 60," Communications of the ACM, v. 6, No. 1, p. 1-17, January 1963.

3. Morriss, Robert, "Scatter Storage Techniques," Communications of the ACM, v. 6, No. 1, p 1-17, January 1963.

4. Programmer's Reference Manual - Floating Point System, DEC-08-YQYB-D, Digital Equipment Corporation, (Maynard, Mass.), 1969.

5. McCracken, D.D., A Guide to FORTRAN IV Programming, John Wiley and Sons, Inc., 1965.

6. Kildall, G.A., BALGOL-2 Programming System, Internal Report, Mathematics Department, Naval Postgraduate School, December 1970.

7. Introduction to Programming, 2d ed., Digital Equipment Corporation, (Maynard, Mass.), 1970.

8. Programmed Data Processor - 8 Users Handbook, Digital Equipment Corporation, (Maynard, Mass.), 1966.

9. Wirth, N. and Weber, H., "EULER: A Generalization of ALGOL, and its Formal Definition: Part I, " Communications of the ACM, v. 9, p. 13-25, January 1966.

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13. ABSTRACT

The design and implementation of the FORTRAN/8 compiler for the PDP-8 computer is described. This compiler was written using the XPL Compiler Generator System and runs on an IBM System 360. FORTRAN/8 accepts FORTRAN as the source language and generates code acceptable for execution on a PDP-8 computer.

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